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FRITZ COHN.*

By P. V. NEUGEBAUER.

Astronomy has had a great loss: on December 14, 1922, the director of the Berliner Astronomisches Rechen-Institut, privy counsellor Prof. Dr. Fritz Cohn departed this life. Only three days earlier he had delivered his lecture in his usual manner, but upon his return to his home the first signs of a malignant stomach trouble appeared and an operation performed the following morning did not avail to save him.

Fritz Cohn was born May 12, 1866, at Königsberg. His youthful years were saddened with trouble and sorrow, as he lost his father very early. Thanks to his exceptional ability and determined application, and in spite of depressing circumstances, he succeeded in passing his examinations and entering the university at the age of 17. He studied at Königsberg and Berlin and completed his studies in 1888 by passing the state examination at Königsberg on the basis of a dissertation on "Lame's Function with Complex Parameters." In 1891 he was appointed as a computer at the Königsberg Observatory, where he remained until 1898. In the mean time he had spent a short time at the Leipzig Observatory. In 1898 he became assistant, and in 1900 observer, at the Königsberg Observatory.

At first his labors at Königsberg were primarily in the computing field; the principal ones being his investigations on the climatic conditions of Königsberg (*Königsberger Beobachtungen*, Band 38), the reduction of Bessel's observations, 1813-1819, (Band 39) and the derivation of the declinations and proper-motions of the stars for the International Latitude Bureau (*Veröff. Erdmessung* N. F. 2). At the same time he began work as an observer with marked activity. Even at Leipzig he had already carried through a series of observations on the latitude of the Leipzig Observatory, the results of which he published in the *Berichte* of the Scientific Association of Saxony. In Königsberg, in addition to numerous observations of a miscellaneous character, he completed his two more important investigations which brought his name into general prominence. These were the "Right Ascensions of the Eros Comparison Stars" and more especially the "Right Ascensions of 4066 Stars" with the transit micrometer of the

*Translated by E. A. F.

Repsold meridian circle. In these two investigations Cohn examined minutely the transit micrometer driven by clock-work and showed that it was possible to achieve results of fundamental accuracy even under the unfavorable conditions at Königsberg. His right ascension observations are among the best of their kind.

From 1893 on Cohn was also active as a teacher in the university. His installation address was on the subject "On Recurring Values and Their Connection with Algebraic Equations" (*Math. Annalen* **44**). In 1895 he became associate professor. In connection with this activity we also find his two articles in the *Encyclopädie der math. Wissenschaften* on "The Theory of Astronomical Instruments for Angle-measurement, the Methods of Observation and their Errors" and "The Reduction of Astronomical Observations."

In October, 1909, Cohn undertook the direction of the Astronomische Rechen-Institut and thus came in contact with an entirely new series of problems. The way in which he succeeded in getting in touch with his new field of work, as well as his increased activity as teacher in the University of Berlin, was admirable.

The *Astronomisches Jahrbuch* was in a critical situation which was ended by the Conference on Ephemerides in the fall of 1911. The new leader of the *Jahrbuch* was not only compelled to get in touch with the many-sided activity of the Institut but also to work out a plan for the transition period. These problems were in accord with Cohn's versatility and his own especial interests. At his suggestion a careful revision of the fundamentals of the *Jahrbuch* were carried out. These are described in the appendix of the *Berliner Jahrbuch* of 1916.

In addition to this came the continuation of the work on the minor planets, the particular field of the Rechen-Institut. Cohn brought to this line of work an intimate understanding, for it was here that his efforts to unite theory and practice found ample room for expression. The writer of these lines can testify how actively he busied himself with problems of this character; the difficulties which the apparent orbit of comet 1910 *a* presented to the computer brought about discussions which often lasted for hours. These discussions brought out clearly, not only his bent to get at the essence of a problem, but also his ability to clear it up from the practical side. How well he understood both is evident in his article "New Methods of Determining Orbits" (*Vierteljahrs-schrift der Astron. Gesellschaft*, **53**) in which, while considering the problem in a wonderfully clear manner from the theoretical standpoint he never forgot the practical point of view.

Cohn did not fail to realize that the treatment of the minor planets according to the traditions of Oppolzer's time could not be carried out. The increasing number of the asteroids, and particularly the terrifying rapidity with which the number of imperfectly observed and therefore lost objects kept mounting, required a thoroughgoing reform. With prompt decision Cohn broke completely with the past and established

as a principle the rule that, with the exception of the first orbit computation, all calculations were to be merely approximate and were to have an accuracy of $\pm 15'$ in longitude for purposes of following the object. Success was attained. By helping personally and continually urging observers to watch for uncertain planets he succeeded in reclaiming many objects that had been given up as lost. Only recently he repeatedly affirmed that he hoped, within a few years, in spite of the loss of his two co-workers, Berberich and Strehlow, to reclaim most of the asteroids.

A further problem also fell to Cohn's lot. Because of ill health Berberich had given up the work on the *Astronomische Jahresbericht*. Through negotiations with the Astronomische Gesellschaft and the government, Cohn assured the continuation of the *Jahresbericht* by adding it to the work of the Institut and himself undertook the preparation of the material for 1910, and later that of 1916 as well. The amount of work these two volumes entailed need not be enumerated, but this much must be said: Cohn did wonders, for this was accomplished in addition to all his other work. He sent the manuscript for 1921 to the printer only a short time before his death.

Cohn was happily married to Johanna Peters, the granddaughter of the publisher of the *Astronomische Nachrichten*. This union was blessed by two daughters and one son. He was socially inclined and a most agreeable companion. His dearest recreation was his garden in which, in season, he was accustomed to work for hours. He never attempted to influence the work of others, leaving each one free to choose his own line of work, even though these were not in accord with his personal interests. Because of his own independent nature he valued independence in others; accustomed to speak his own mind freely he delighted to discuss subjects with those having opposing opinions, which he often brought out by asserting the contrary. All who came in contact with him recognize what a loss his departure represents both as a man and as a scholar.

Berlin-Steglitz, Albrechtstr. 18.

ON A PROBABLE DISTRIBUTION OF THE PLANES OF THE ORBITS OF SPECTROSCOPIC BINARIES IN SPACE.

By G. SHAJN.

The Milky Way appears in a manner a fundamental plane of the whole stellar system. We may also assume that all motions occur in preference in the plane of the Milky Way. We will examine only one detail, namely, the distribution of the orbits of spectroscopic binaries. We make two assumptions: (1) the sun is situated not far

from the centre of the stellar system; and, (2) the planes of the orbits of spectroscopic binaries lie parallel to the plane of the Milky Way. Both these hypotheses are very uncertain.

At the poles of the Milky Way the projected orbit will seem normal to the line of sight and the spectrograph therefore cannot detect the duplicity of the star. Per contra, in the Milky Way, the probability of detecting the duplicity of a star will be considerably greater.

The hypothesis of preferential motion must be manifest in the distribution of stars, i. e., the concentration of the spectroscopic binaries must be greater in the Milky Way than at its poles, aside from the general aggregation of the stars in the Milky Way. If the first assumption is untrue, then even under complete parallelism of the orbits with the plane of the Milky Way, the discovery of a spectroscopic binary at the poles is very probable. The angle of the inclination in relation to the plane normal to the line of sight depends upon the parallax (π) of the star and the projection (R) of the distance of the sun from the geometrical centre of the central plane of the Milky Way, so that

$$\sin x = \pi R \sin 1'' / a$$

where a = radius of the earth's orbit.

For the investigation of this question Voute's "First Catalogue of Radial Velocities" was employed. In this I found 1749 single stars, 172 spectroscopic binaries with known orbits, and 452 with unknown orbits or of suspected duplicity.

The whole sky was divided into four equal parts: galactic latitudes $\pm(0° - 14°.5)$, $\pm(14°.5 - 30°)$, $\pm(30° - 48°.5)$, and $\pm(48°.5 - 90°)$. Table I gives the number of the stars of the different spectral types.

TABLE I.

Class Galactic Latitude	B	A	F	G	K,M
	147	77	70	90	188
±(0° - 14°.5)	27	14	10	14	4
	97	36	24	19	39
	67	67	61	58	169
±(14°.5 - 30°)	23	16	10	7	2
	30	32	11	9	32
	30	82	48	82	153
±(30° - 48°.5)	6	10	6	1	3
	7	23	10	8	22
	16	86	43	57	152
±(48°.5 - 90°)	1	7	5	2	2
	2	18	5	6	12

First line in each group of three gives the number of the single stars.

Second line in each group of three gives the number of spectroscopic binaries with known orbits.

Third line in each group of three gives the number of spectroscopic binaries with unknown orbits.

It is known that the stars show a concentration in the Milky Way. The faint stars exhibit this particularly; but the bright stars, down to magnitude 5.5, are distributed more uniformly, excepting those of Class B and Class A in part. To judge of the distribution of the spectroscopic binaries, it is necessary to compare it with the distribution of the single stars of the corresponding spectral types (*Annals of Harvard College Observatory*). However, the distribution of the spectroscopic binaries as to brightness is sufficiently definite (a considerable majority lie between $3^m.0 - 5^m.5$). For that reason, in Table II we give the relative concentration of the stars for the galactic half of the sky $\pm(0° - 30°)$ in relation to the non-galactic half $(30° - 90°)$ both for the single stars and for the spectroscopic binaries, employing in both cases only the "First Catalogue" of Voute, because the investigation of radial velocities for certain reasons cannot include all stars of definite magnitude.

TABLE II.

RELATIVE CONCENTRATION IN THE GALACTIC HALF OF SKY.

Spectral Type	B		A		F		G		K.M	
Single Stars	4.6	214 / 46	0.9	144 / 168	1.4	131 / 91	1.1	148 / 139	1.1	357 / 310
Spectroscopic binaries (known orbits)	7.1	50 / 7	1.8	30 / 17	1.9	21 / 11	7.0	21 / 3	1.2	6 / 5
Spectroscopic binaries (unknown orbits)	6.7	127 / 19	1.7	68 / 41	2.3	34 / 15	2.0	28 / 14	2.1	71 / 34

If we take more limited latitudes ($0° - 14°.5$ and $48°.5 - 90°$), then the correlation will remain the same or be even more evident.

From Table II it is easily seen, that in the galactic half of the sky the spectroscopic binaries are much more concentrated than the single stars. Although it is impossible, evidently, to speak of a complete parallelism of their orbits, however, the peculiarity of the above table shows *that the spectroscopic binaries probably have a preferential orbital motion in the plane parallel to the Milky Way.*

The investigations of See, Everett, Turner, Lewis, and Doberck relative to a few score of orbits of visual double stars manifest no marked peculiarity in their distribution. H. N. Russell and H. Shapley find that the eclipsing variables show a strong concentration towards the galactic plane. A similar result has been found by E. Hertzsprung for short-period variables and by W. Gyllenberg for long-period variables; the result found here is in agreement with these, although out of 172 spectroscopic binaries only 28 are variables.

Pulkovo, April, 1922.

LEAP YEAR RULES AND CALENDAR ACCURACY.

By CHARLES F. MARVIN.

SYNOPSIS.

An accurate calendar, in the sense with which this analysis is concerned, is one by which the civil reckoning of time keeps very closely in step with the march of the astronomical seasons for many centuries. Good leap year rules are those that are very simple and provide for the fractional part of a day required to express the true length of the year so that no accumulated error greater than small fractions of a day are possible in the reckoning for a very long time.

Hitherto the makers of calendars regarded the length of the year as constant, when measured in days, whereas it is now known that the length of the year so measured is growing shorter at the rate of about 0.53 seconds per century. The theory of the effect of this small change on leap year rules and calendar reckoning is developed *on the basis that the rate of change is correctly known as at present and remains constant.*[1] It is shown that the Gregorian rule of omitting 3 leap years in 400 years is outliving its usefulness. The error of reckoning is becoming greater and greater and will amount to a whole day about 3600 A. D. Pope Gregory might have adopted a rule to omit 4 leap years in 500 years and secured a calendar which would have run to 13,000 years A. D. before the error became as great as 1 day, whereas the present rule will introduce an error of 7.6 days at that time.

The present rule had best be continued to the year 3200 A. D., when the error of reckoning will be about 0.9 day. Then introduce a rule to omit 5 leap years in 600 years, resulting in a calendar which will operate until the year 17600 with errors well under one day throughout the whole period.

HISTORICAL.

For countless ages, the mind of man has labored to devise a calendar by which to register the passage of time so that the return of springtime and harvest, and the whole train of events that constitute the march of the seasons, shall all occur perpetually and minutely at the same identical place in the civil reckoning. Convenience and adaptation to human needs in other particulars are also essential qualities of any acceptable type of calendar, but any defect which tends to carry the seasons forward or backward over the dates of the calendar leads ultimately to serious errors of reckoning which cannot be tolerated.

In the most primitive ages the dawning intelligence of man recognized only the day of sunlight and darkness as the natural units by which he could measure the passage of time. The cycle of the lunar month was next discerned, but its wholly incommensurable relations to the day baffled the understanding of ancient scientists and caused much confusion and inaccuracy in attempts to calendar the passage of time by lunar months. Ignorant of the true relations between members of the solar system, and lacking suitable means for making astronomical observations, many centuries of time elapsed before the length of the

[1] See foot note p. 301.

year, as measured by days, emerged from the accumulated experience and crude observations of the wise men and astrologers of the remote past.[1]

The length of the year expressed in days and fractions must be known with great accuracy before it is possible to plan a calendar that will keep exactly in step with the solar year for very long periods of time. The philosophers and priests of Egypt appear to have been the first to learn that the solar year contained, very approximately, 365¼ days and to construct an excellent civil calendar upon this basis. These discoveries seem to date back to the time of the great pyramids, about 2000 years before the beginning of the Christian era, and probably form the basis and prototype of the Julian and Gregorian plans of reckoning of the Christian era.

Any single year of civil reckoning must necessarily contain an exact whole number of days which we now know must be 365 or 366 days. The artifice of the so-called "leap-year" serves to care for the fraction of a day necessary to express the true length of the solar year. Since the rule for intercalating leap years cannot be quite perfect in any case (except in an accidental and temporary way) the solar and civil reckoning cannot keep perfectly in step for an indefinite time without some change in the rule. The Julian rule of one leap year in four makes the civil year more than 11 minutes too long.

Only a few hundred years of reckoning by this rule sufficed to show that it was seriously faulty and that the date of the spring equinox was slowly retrograding towards January from the 25th of March, its original place in the calendar in 46 B. C.

Fifteen centuries of faulty reckoning followed, however, before the opposition of popular sentiment to changes in fixed customs could be overcome and the imperfect Julian system displaced. This was accomplished by a brief issued in March, 1582, by Pope Gregory XIII, who ordered the system now in use by nearly all the great nations of the earth. The Gregorian rule calls for a leap year every fourth year, except that three leap years are omitted in each 400 years. In order to eliminate some of the error of regression introduced by the Julian reckoning, and to restore the date of the spring equinox to the 21st of March, the date on which it fell at the time of the Council of Nice, 325 A. D., Pope Gregory ordered that ten days be suppressed from the reckoning by making the 5th of October, 1582, the 15th of that month. This calendar is one of great accuracy, but as will be shown later a far better one might have been introduced, and the time is not so far distant when some modification will require to be considered.

[1] A history of calendar making among primitive civilizations has been written, with many interesting details, by M. B. Cotsworth in a pamphlet entitled "Time to fix the year," published by International Almanac Reform League, New Westminster, B. C., Canada. See also Bulletin Pan American Union, June, 1922.

Revision of Leap Year Rule Necessary.

The real purpose of the present paper is to apply modern exact astronomical knowledge to calendar reckoning and leap year rules, in order to develop the mathematical theory of the error of reckoning and to show the necessity for certain changes in the rule for leap years if the present civil calendar is to continue indefinitely to keep accurately in step with the march of solar events.

Temporary and Permanent Errors. There are different kinds of errors of reckoning which may be designated temporary errors, and average or permanent errors. The temporary errors are those which occur in the years between the leap years, or those running through the periods of 400 years during which the three leap years are being omitted by the Gregorian rule. The permanent errors are the small inevitable cumulative errors by which the civil reckoning *on the average* lags behind or runs ahead of the solar years, because no simple leap year rule can continuously keep the length of the civil year exactly the same as that of the solar year.

The full nature of these errors is most easily understood from a diagram like Fig. 1, which shows the calendar errors in a cycle of 400 years by the Gregorian reckoning. The cycle begins at *a* on February 28 of a leap year century. The *permanent* error of reckoning at this

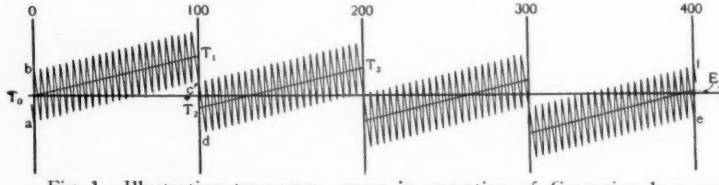


Fig. 1. Illustrating temporary errors in operation of Gregorian leap year rule, which adds one day in four years, except that three additions are omitted in 400 years.

time is assumed to be zero. The *temporary* error of February 28 is then —0.5 day and the intercalation of February 29 causes the *temporary* error of March 1, at *b*, to be +0.5 day, that is, the true reckoning is midway between.

The *average* reckoning for the next 100 years follows the line $T_0 T_1$ with changing values of the temporary errors. On February 28 of the 100th year, that is, at *c*, the reckoning is about 0.25 day ahead; however, the *omission* of a leap day otherwise due at this time causes the temporary error four years later to become about —.75 of a day as at *d*. By the further omission of two additional leap days in the years 200 and 300, the reckoning is finally brought back at the close of the cycle to *e* on the 28th of February of the year 400, with a temporary error of about —0.5 day. This century is a leap year by the rule, and the temporary error of March 1 is restored to about +0.5 day, the same as at the beginning of the cycle. In spite of these adjustments,

however, there is still a small outstanding *permanent* error indicated at E, and it is the major purpose of this article to analyze and evaluate such permanent errors in order that proper leap year rules may be formulated which will operate for very long periods and give minimum errors.

When the Civil and Solar Years Coincide. It will be noticed as a result of the foregoing analysis that the temporary errors are zero for a time before and after February 28 of the middle century of a 400-year cycle, also that the true reckoning, disregarding the permanent errors, falls midway between February 28 and March 1 at the beginning and ending of the cycle. We may regard such years as *average* years to which the permanent errors, computed by the formulae to be developed later, will apply.

Solar Year not Constant.[1] For a long time astronomers have recognized that the ceaseless reaction of the ocean tides must inevitably slow up the rotation of the earth on its axis and hence increase the length of the day, that is, shorten the year when its length is measured in days. Other influences, like erosion, meteoric bombardment, contraction or expansion of the earth, etc., might also change the time of its rotation. However, the utmost study of these questions leads to the conclusion that the change due to any or all of these causes is quite too small to evaluate with certainty or to require consideration in such problems as the present one. In other words, the period of rotation of the earth on its axis is one of the most constant elementary motions of the solar system. When, however, a very critical examination is made of the length of the tropical or civil year, which is measured by the return of the sun to the same equinoctial point of the ecliptic, it is found that the year at the present time is slowly becoming shorter. This is due to the attractions of the sun and moon for the bulging ring of matter about the earth's equator causing the phenomenon known as the precession of the equinoxes. Associated with this effect

[1] Grateful acknowledgment is made here of the able and generous assistance of Capt. W. S. Eichelberger, Director of the Nautical Almanac, with reference to the exact manner in which the length of the tropical year changes over the great periods of time covered by the operation of the leap year rules herein discussed. He points out that the rate of change due alone to precession and secular perturbations is subject to large and complicated changes over long periods of time. The present rate is perhaps in the nature of a maximum.

Again, secular orbital acceleration of motion, also the small tidal effects, cannot be neglected in the final evaluation of calendar effects due to any particular leap year rule. The net outcome of all such considerations, as applied to the present problem, is simply that the rate of change in the length of the tropical year, however caused or however much the change itself may vary, must be duly considered and by the judicious selection of an appropriate leap year rule its useful life can be very greatly prolonged. The method by which such results are attained are indicated in the paper. Entire accuracy is not claimed for the numerical magnitudes given, but by the use of a *mean* value for the rate of change over the intervals covered, instead of the exact value for the present time, the final results would become more accurate.

there are also the very long time planetary perturbations in the eccentricity of the earth's orbit and its inclination to the ecliptic. The length of the year cannot, from these causes, continue to shorten indefinitely, but will cease to change after a time and lengthen again in the remote future. In order to develop the present theory, and in the absence of exact knowledge as to how the length of the year will change during the next 20,000 years, we shall assume that the present rate of change *will continue constant*. When later astronomical observations supply the real facts, corrections can be made, if necessary, to conclusions we may state based on this assumption.

The change in the length of the year was quite unsuspected by the early calendar makers. In fact, the rate of change has been satisfactorily evaluated only within very modern times, and the present writer is not aware of any other attempt than this to seriously calculate the effects on calendar reckoning caused by the slow change which is taking place in the length of the tropical year.

Briefly stated, the effects are appreciable and no fixed rule of any kind will suffice to keep the civil calendar continuously in step with solar sequences. A single rule, however accurate at any one time, will later become increasingly faulty and must be modified or replaced.

A little examination of the errors resulting from the operation of any rule shows that there are good and bad rules and that every rule has a definite period of maximum efficient operation.

Good Rule Defined. A good rule for leap years may be defined to be one of great simplicity but that nevertheless operates for a long time and does not introduce errors of reckoning which exceed, say *half a day*. Greater errors, even as great as a *whole day* or more, may be tolerated perhaps, *provided the errors tend to grow smaller as the rule operates*. It will be shown later that a rule properly chosen and operated on the foregoing basis will have an effective life of about 100 to 150 centuries and must then be replaced.

Assuming that the present rate of change in the length of the year has been constant, it can be shown that the Gregorian rule is a rule for the past, not for the future. This rule would have operated with ideal efficiency at about 3006 years B. C. The rule is still very satisfactory, but it is rapidly outliving its usefulness. A slight modification, however, will restore it to effective operation and give it new life for a period of at least 8,000 years, during which time the error of average reckoning will attain to and exceed half a day only in the far-distant future.

Theory of Leap Year Rules.

The average length of a civil or calendar year may be represented by an expression,

$$L_c = 365^d + f_c$$

in which f_c is a fraction of a day determined by the rule for leap years.

By the Gregorian rule

$$f_c = 1/4 - 3/400 = .2425$$

which remains constant until a different rule is followed.

From the results of Newcomb's investigations, fully confirmed by other authorities, it is now known that the length of the mean tropical year is represented by the equation[1]

$$L_s = 365^d + f_s - bt$$

in which f_s and b are small fractions, $b = .0000000614$, and if t is measured in years from the beginning of the Christian era, $f_s = .24231545$. The difference between the two reckonings at the end of a single year will be

$$y = L_c - L_s = a_t + bt \qquad (2)$$

When the value of y is positive the civil count contains too many days, and vice versa.

In equation (2), a_t represents the value of $f_c - f_s$ at the epoch from which t is measured, which for convenience in the present computations is taken at the beginning of the Christian era. If E represents the permanent or accumulated difference between the civil and solar reckonings after a given rule has been in operation for n years measured from the epoch t, then

$$E = \int ydn = \int (a_t dn + bndn)$$

$$E = a_t n + bn^2/2 + c \qquad (3)$$

which is a general equation for the error of reckoning after n years. The constant c has a zero value if the civil and solar reckoning start in accord at the beginning.

Equation (3) represents a parabola, the curvature of which depends entirely upon the value of b, which is wholly beyond control because it is determined by astronomical relations. Therefore, it follows that the error curves for all leap year rules are identical in form and differ only in their positions with reference to the coördinate axes.

A little consideration of this matter shows that for the best possible results the error curve should be disposed as shown at A, Fig. 2.

Starting at the epoch t where $n = 0$, E must have a small positive value, c, say 0.5 day. Thereafter the error diminishes to a maximum negative value which should also, if practicable, be approximately 0.5 day. The error thereafter increases towards positive values, which later become greater and greater, and the rule must ultimately be replaced by a new one if the reckoning is to keep in step with the solar year.

The mathematical relations which must be satisfied to realize these ideal conditions of operation are easily formulated as follows:

[1] American Ephemeris & Nautical Almanac, 1922, p. XVI. Astronomical Papers, American Ephemeris, Vol. VI, p. 10.

The value of c must be positive. The coefficient a_t must be negative and have a value which will make the maximum negative error, E', a small fraction of a day which may be more or less arbitrarily assigned.

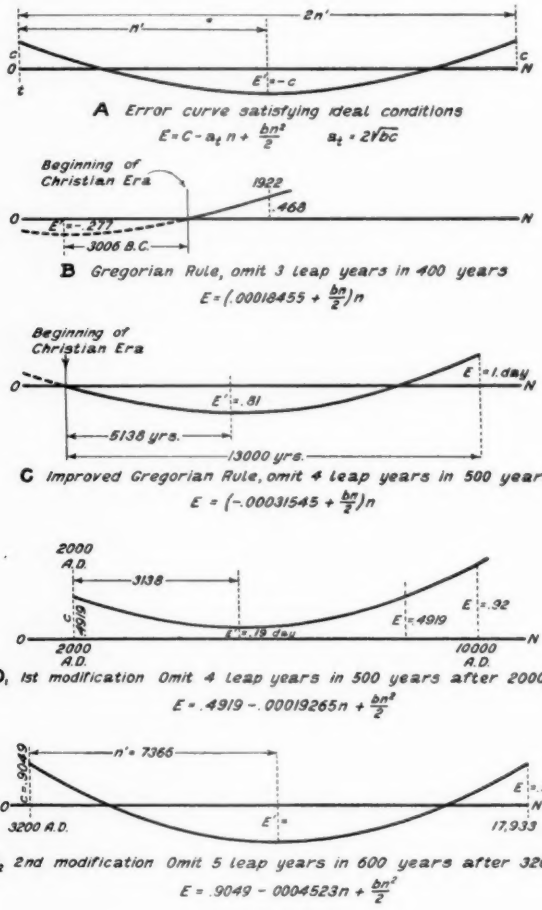


FIG. 2.

By differentiation we find from equation (3) the maximum negative value occurs when $n = n' = a_t/b$ for which

$$E' = c - a_t^3/2b = c - a_t n'/2$$

(The equation $E' = c - a_t n'/2$ is convenient for computing the maxi-

mum value of E for $n_* = a_t/b$), and

$$a_t = \sqrt{2b\,(c - E')} \tag{4}$$

This is a general equation giving the value which must be given to a_t in order to satisfy some predetermined value of c and some assigned maximum negative value of E'. In a general way it may sometimes prove practicable to make $E' = -c$. This will place the useful portion of the error curve equally above and below the time axis, ON, Fig. 2. For this case

$$a_t = 2\sqrt{bc} \tag{5}$$

It will only occasionally be practicable to attain the ideal conditions represented by equation (5) because no simple rule for recurrence of leap years can be found that will make $f_c - f_s = a_t$ as given by equation (5). Nevertheless it will be useful to compute a few values in order to define limiting conditions and some leap year rule can often be found that will approximate more or less closely to the ideal. Thus:

(1) Put maximum negative error $E' = -0.5$ day, also initial and final error, $c = +0.5$ day.

$$a_t = \sqrt{2b} = .000350428$$

For this case the time of the maximum negative error,

$$n' = a_t/b = 5707.3 \text{ years after the epoch } t.$$

Whole useful life of rule $= 2n' = 11415$ years.

(2) For $c = 1$ and $E' = -1$

$a_t = 2\sqrt{b} = .00049558$; n' = time to maximum = 8071.3 years.

Whole useful life, extreme errors 1 day $= 2n' = 16143$. years.

Thus we see that for ideal conditions the value of a_t may range between .00035043 and .00049558, with extreme errors ranging between half a day and one day and with a life of useful operation of from 11400 to 16000 years.

Practical Applications.

It will be interesting to see how the foregoing theory works out in a few practical cases.

Julian Reckoning. The Julian rule of one leap year in every four was establishel in the year 46 B. C., which is an average year by the definition already given, hence if the Julian rule were a good one the date of the spring equinox, for example, would have occurred indefinitely thereafter at the same place, March 25, in the calendar. For this rule

$$f_c = 1/4 = .25000$$

From Newcomb's formula for the year 46 B. C., $f_s = .24231827$

therefore $a_t = f_c - f_s = .00768173$

and $n' = -a_t/b = -125110.$ years.[1]

Thus the large magnitude of a_t together with the positive sign indicates that the Julian rule, when adopted, was long past its period of useful operation.

Gregorian Rule. There is no clearly defined date or epoch which can be assigned as the beginning of the Gregorian reckoning. In order to compute errors of reckoning introduced by this calendar an arbitrary ruling is necessary to fix the time at which the reckoning begins and the amount of its initial error, if any.

The omission of 10 days from chronology when the reckoning was introduced in 1582 was intended to have the retroactive effect of fixing the nominal beginning of the calendar at 325 A. D., the date of the Council of Nice, and to restore the date of the spring equinox to March 21. As a matter of fact, however, the rule itself would omit only 9 days between 325 and 1582, namely the leap days in the centuries 5, 6, 7, —9, 10, 11, — and 13, 14 and 15. We may, therefore, assume that the omission of 10 instead of 9 days actually carries the calendar back to the year 200 A. D. and, by reference to Fig. 1 and its explanation, it is seen that the *temporary* error at the mid-century of a 400-year cycle is zero. Therefore, decidedly the simplest decision we can reach is to fix the beginning of the Gregorian reckoning at the beginning of the Christian era, which is also the beginning of the first 400-year cycle defined by the Gregorian rule. We may also assume the initial permanent error was zero. This assumes that the leap days falling at the 29th of February in the years 100 and 200 were actually omitted, which of course was not the case, but this fault will not affect in any way the accuracy of the computations which will be made later in this paper.

The force of the foregoing analysis serves to demonstrate also that events of chronological reckoning by the Julian calendar fall two days later during the first century A. D. and one day later in the 2nd century than the same events reckoned by the Gregorian calendar. This is because the latter assumes the omission of the leap days in the years 100 and 200 A. D.

Table I gives values of E computed in accordance with the foregoing from an equation of the form of (3) the constants of which are evaluated as follows:

$$f_c = 1/4 - 3/400 = .242500.$$

f_s at beginning of Christian era $= .24231545.$

$$a_t = f_c - f_s = +.00018455,\ c = 0.$$

Therefore $E = (.00018455 + bn/2)n$

$$n' = -a_t/b = -3005.7,\ E' = a_t n'/2 = -.277 \text{ day.}$$

See error curve B Fig. 2.

[1] No significance attaches to this result, however, because so little is known as to how the length of the year actually changed over this long period.

TABLE I. Values of the length of the year at various dates by Newcomb's equation and the permanent errors, E, introduced by the Gregorian reckoning.

n Year A. D.	Length 365^d+	E days
1	0.24231545	0
325	0.24229549	0.0632
400	0.24229089	0.0787
1582	0.24221832	0.3688
1922	0.24219744	0.4681
2000	0.24219265	0.4919
2400	0.24216089	0.6198
2800	0.24214353	0.7574
3200	0.24211897	0.9049
3600	0.24209441	1.0622
4000	0.24206985	1.2294

NOTE. The unknown error in the absolute length of the year is of the order of about 0.2 of a second. The change per year in the length is known for the present time within less than one-hundredth of a second, therefore the number of significant figures in the data of the table is justified under the theory.

The values of E in this table give the amounts at different dates by which the Gregorian reckoning is running ahead of the true solar time, and some change in the leap year rule must be made at an appropriate time in the future if the accuracy of the calendar is to be preserved.

Let it be asked at this point if a better rule than the Gregorian one could have been proposed originally. What follows will show that the rule should have been to omit 4 leap years in 500 years instead of 3 in 400 years. By such a rule

$$f_c = 1/4 - 4/500 = .242000$$
$$f_s = .24231545$$
$$\text{therefore } a_t = -.00031545$$

therefore $n' = a_c/b = 5137.6$ years, $E' = a_t n'/2 = -.8103$ day.

This error curve is shown at C, Fig. 2.

This rule gives very nearly ideal results and might just as well have been chosen even without knowledge of the change in length of the tropical year which gives a certain advantage in its operation. If this rule had been adopted at the beginning of the Christian era, assuming no error of reckoning at that time, a maximum negative error would have developed of only .81 day after more than 5100 years. The error would have become zero again after 10300 A. D. and would become about $+1$ day about the year 13000. Thus we see that the rule of omitting 4 leap years in 500, which Pope Gregory might have been advised to adopt, would have given a calendar practically free from error for 130 centuries, whereas by Table I we see the error by the Gregorian rule attains 1 day in 3600 years. In 13000 years the error becomes $+7.6$ days.

Modifications of Gregorian Calendar. In concluding this discussion of calendar accuracy, mention will be made of just two of several pos-

sible modifications of the present calendar to meet future needs.

First Modification. It is not too late to take advantage of the rule of omitting 4 leap years in 500 years. If adopted to begin with the year 2000, the error equation becomes:

$$E = .4919 - .00019265\,n + bn^2/2 \quad \text{(See } D_1 \text{ Fig. 2.)}$$
$$n' = 3137.6 \quad 2n' = 6275. \text{ years.}$$
$$E' = .4919 - an'/2 = + .1897$$

This error curve lies wholly above the axis, and the rule may be continued until about 10000 A. D., at which time the error becomes + 0.9155 day.

Second Modification. Continue the present rule until the year 3200, which is a leap year, and by Table I the error of reckoning is +0.9049 day. At this date introduce a leap year rule which omits 5 leap years in 600 years. This gives an error equation as follows:

$$E = .9049 - (.0004523 - bn/2)\,n \quad \text{(See } D_2 \text{ Fig. 2)}$$

The value of a_1 in this equation very nearly satisfies the ideal conditions and the rule is, therefore, a very good one.

$$n' = 7366.4,\ E' = -.761 \text{ day.} \quad 2n' = 14733 \text{ or } 17933 \text{ A. D.}$$

at which date E will again be the same as the initial error, .9049. The year 17600 will be a leap year and E will then be 0.7577 day. A new leap year rule will then again be needed to preserve and maintain the present accuracy of the Calendar reckoning.

Long before this time astronomers will have far more definite knowledge concerning the law of change in the length of the year and it will then be possible to write equation (3) which gives the error of reckoning in a more accurate from than is now possible.

ROBERT WHEELER WILLSON.

By H. T. STETSON.

It is with deep regret that we have to record the loss to Astronomy of Professor Robert Wheeler Willson, whose sudden death on the first day of November (1922) terminated a long career of service, devotion, and benefaction to science, to education, and especially to Harvard University, his Alma Mater, for whom he always held the warmest affection and where he was actively connected with the faculty for more than a quarter of a century, serving successively in the capacities of tutor, instructor, assistant professor, and professor; and, for nearly fifteen years, a member of its administrative board.

In tracing the early events in his life, we learn that he was born in West Roxbury, Mass., July 20, 1853, the eldest son of Rev. Edmund

B. and Martha Butterick Willson, his mother's grandfather being Major John Butterick, who led the Concord fight in the Revolutionary War.

When Robert Willson was six years old, his parents removed to Salem, where his father became minister of the North Church, Unitarian, holding the pastorate for thirty-seven years, the remainder of his life. During the Civil War, he was granted leave of absence by his parish and served as chaplain of the 24th Massachusetts Regiment, an incident of which Professor Willson seldom spoke, but which made a strong appeal to his sense of loyal patriotism and devotion to duty.

His early education was in the public schools of Salem, where he showed marked ability as a student, graduating with honors at the age of fifteen. His constant association with the port of Salem during the impressionable years of his career doubtless early instilled that fondness for things nautical which he kept through life, and which, later in his career, was to lead his attention to the application of Astronomy to Navigation and the development of improved instruments and methods in this cause.

In the fall of 1869 Willson entered Harvard University, one of the youngest members of his class. His buoyant and jovial enthusiasm won him many friends among classmates, and found expression in many of the student activities of the time. He was a member of the Glee Club, a favored performer of the Pi Eta (a dramatic organization), and was called the Prima Donna of his class. In his studies, he developed an aptitude for science and showed a special fondness for Physics and Chemistry. As an illustration of his ready wit and youthful merriment combined with scientific ingenuity, certain members of his class will recall the installation of the "college telegraph", with its accompanying somewhat exclusive organization which counted among its members Wheeler, Thorp, and Byerly. The "telegraph" established interdormitory communication by means of all but invisible wires, a daring challenge to the rigid college discipline of those days. The contrivance does not appear to have been purposely discovered by the college authorities. If so, disciplinary action seems not to have been taken, possibly out of due regard to the cause of potential scientists.

The more serious side of undergraduate life, however, was not forgotten, for we find Willson graduating in the class of 1873, receiving his degree of Bachelor of Arts *cum laude* and with highest honors in Physics and Chemistry.

Little opportunity was then open to the undergraduate to learn Astronomy. In 1872-3, a short course in Astronomy was given by Professor Lovering in connection with a course in Acoustics. Willson was early fascinated by the subject; and when the opportunity came upon graduation to assist Dr. B. A. Gould at the Argentine National Observatory, he gladly accepted, and went immediately to South Am-

erica, where he spent a year in the work of the Observatory there. The following year he returned to Cambridge, to become assistant in the Harvard College Observatory under the direction of Joseph Winlock, and was greatly impressed with the assignment of duty to the then great 15-inch Equatorial.

During the years 1875-81, he served as tutor in Physics at Harvard, after which he went to Yale as Assistant Astronomer in the Winchester Observatory. In December, 1881, he married Annie Downing West, of Salem, Mass., who survives him. While at Yale, he had the unusual opportunity of being able to participate in a campaign organized for observing the transit of Venus on December 5, 1882, from which the solar parallax was redetermined.

Little opportunity for taking advanced degrees in Physics and Astronomy was to be had in America at that time; and in 1884 Willson went to Germany for further study, receiving the degree of Doctor of Philosophy *magna cum laude* from the University of Würzberg in 1886. Shortly after returning to this country, he collaborated with Professor Benjamin O. Peirce in the investigation of problems of heat conductions; and in 1891 was appointed instructor in Physics and Astronomy at Harvard. At the time of his appointment, there was no course in Astronomy given at the University, except as comprised in a course in spherical Trigonometry with applications, given by the Department of Mathematics. The Harvard College Observatory, being devoted exclusively to research, offered no instruction in Astronomy. With opportunity for teaching in his chosen field, he immediately began to build up substantial courses in Astronomy. In 1899, he received the appointment of Assistant Professor of Astronomy; and in 1903 was made full Professor, which position he held until his retirement in 1919 as Professor Emeritus.

With the rapid spread of laboratories of Physics, Chemistry, and other sciences, Professor Willson visualized a laboratory for Astronomy, and was a pioneer in the devising of apparatus and methods which should accomplish for the student of Astronomy what laboratory work in other fields was doing for the allied sciences. In 1903, when the wooden building previously held by the Architectural Department was abandoned for the more commodious quarters of Robinson Hall, the present Astronomical Laboratory was established. Professor Willson interested others in the enterprise, secured loans and gifts of apparatus or funds, and spared himself neither time nor means to acquire an equipment adequate for instruction in Descriptive and Practical Astronomy. Extensive alterations were made in the main building, and separate shelters for instruments were erected in the yard, largely at his own expense. In 1906, by an agreement with the Corporation, apparatus and material representing a large personal investment were given to the University, to be used in maintaining courses of instruction in Astronomy and in its several branches.

Professor Willson's enthusiasm for his favorite science won him many friends among his students as well as his professional associates. He believed firmly in the educational advantages of Astronomy, and deplored the great ignorance often displayed by otherwise educated people concerning the most obvious of astronomical phenomena. As a teacher, he gave of his time unstintingly to clarify the more obscure parts of his subject, and was a master and a genius in the development of apparatus to demonstrate in a moment what otherwise hardly, if ever, could be satisfactorily explained. Other institutions, learning of the novel development in Astronomy at Harvard, began to establish laboratory work in Astronomy, and increasingly looked to him for suggestions and guidance in the acquisition of material and the development of methods.

It was his constant desire, not only to provide the best of equipment for laboratory instruction at Harvard, but to have such material and methods available for courses elsewhere. Charts, diagrams, and many special pieces of apparatus were devised; and in many instances arrangements were made for quantitative production. While engaged in such work, he found time to embody most of his ideas and methods in his book, "Laboratory Astronomy," published by Ginn and Company, which appeared in two successive editions. At a later date, he published "Sunrise and Sunset" in the United States, the results of a series of calculations, the remuneration from which went to the laboratory for the purchase of a Riefler Sidereal Clock, the highest grade astronomical timepiece manufactured.

In his courses in practical Astronomy, which were brought to a high degree of efficiency, he numbered among his pupils A. Hamilton Rice and Donald B. MacMillan, in whose training for explorations in remote parts of the earth he had taken no small part. It was most natural that when the Harvard Travelers' Club decided to publish a "Handbook of Travel," Professor Willson was selected for author of the section on "Determination of Position by Astronomical Observations," one of the most important sections of the volume.

While Professor Willson's chief life work was concerned with the teaching of Astronomy, which he ever regarded as of equal importance with research, he was by no means idle as an investigator. Among his earlier contributions should be mentioned the development of rotating and conical prisms for the positional observations of the sun, reducing the sun's disk to a small spot in the field of the telescope, thereby making possible observations of its transit with nearly the same facility as of a star image. For a number of years, he was at work on the design and construction of a new form of bubble sextant which should make unnecessary the use of a horizon in the measurement of altitudes at sea or on land; and when the war brought exacting demands for navigational instruments for aviation, the Willson

Bubble Sextant was thoroughly tried out and found to be superior to any similar invention. Professor Russell of Princeton, basing his remarks on more than a thousand observations in flight, has said of it: "The bubble sextant appears to leave little to be desired as an instrument for aerial navigation . . . . . and gives a precision of observation much surpassing the limit set by the small irregularities in even the best piloting." Other instruments facilitating air navigation were devised by Professor Willson, and included a computing rule and box sight for determining ground speed.

Professor Willson's interest in aviation was aroused at the time of the aviation meet at Cambridge in 1910, when he assumed the responsibility of determining accurately by triangulation the record flights for altitude of Brookins and Grahame White in the demonstrations at Squantum.

The variety of his interests led him to gain familiarity with the early writings of the Maya peoples of Central America. An examination of the astronomical tables of the Dresden Codex suggested to him the possibility of determining with considerable certainty the epoch of the calendar. Reasoning first from the evidence of the eclipse tables, and later from the pages of the planetary tables, he devoted a large part of his spare time from 1915 to the last year of his life in carrying through an exhaustive study involving many long and laborious computations.

The results of his investigations, which he prepared for publication but a few weeks before his death, led him to the conclusion that the zero day of the Maya Calendar 4 Ahau 8 Cumhu was probably the same as August 29, 3512 B. C., as ordinarily reckoned by the chronologist.

Professor Willson's early astronomical training lay chiefly in the older branches of Astronomy known as meridian circle work, calling for great exactness in observation and the utmost vigilance for instrumental and observational errors. This undoubtedly fostered a habit of critical examination of every piece of scientific work before unquestioned acceptance on his part of any results; and he subjected results from his own endeavors to the same critical standards of judgment which he demanded of others. This habit of searching inquiry in many instances deterred him from making public preliminary results of long investigations in many lines, which another with a less hesitant attitude would have published freely. He was never content with the partial solution of any problem. However important the intermediate step might be, or however long he may have been at work upon a given investigation, he was always hoping for the complete solution or the perfected method, and appeared dissatisfied at publishing anything less.

Professor Willson was much interested in the early history of Astronomy and its allied subjects, read Latin with comparative ease, and

found pleasant relaxation in the collecting of rare volumes, early printings, and autographed copies of the masterpieces of science. He prized especially highly a presentation copy of Galileo's Dialogues, published in 1632, inscribed presumably in the handwriting of its author.

Apart from Astronomy, he was deeply interested in the public good. In 1917, he was elected a member of the special committee of the Boston Chamber of Commerce for considering the Daylight Saving Plan, and used his technical knowledge and skill in the accumulation of evidence to favor its adoption for the public good.

His quick perception, breadth of knowledge, and wealth of experience kept his mind always active. The work he had planned to accomplish after retirement fully occupied him to the end, and the unfinished tasks he was obliged to leave stand as silent witnesses to his cherished ambitions and his unmitigated zeal. His attainments as a scientist and as an educator won him wide recognition. He was a member of Phi Beta Kappa, the American Astronomical Society, a fellow of the American Association for the Advancement of Science, and of the American Academy of Arts and Sciences.

As a teacher, he was highly esteemed by his students and by his colleagues. His genial personality, unfailing sense of good humor, and indefatigable optimism won many friends and transformed many a hopeless circumstance into noteworthy achievement. Those who worked with him and came to know him intimately found in him a wise counselor and a trusted friend.

Harvard University, February, 1923.

THE VARIABLE STAR SS CYGNI.

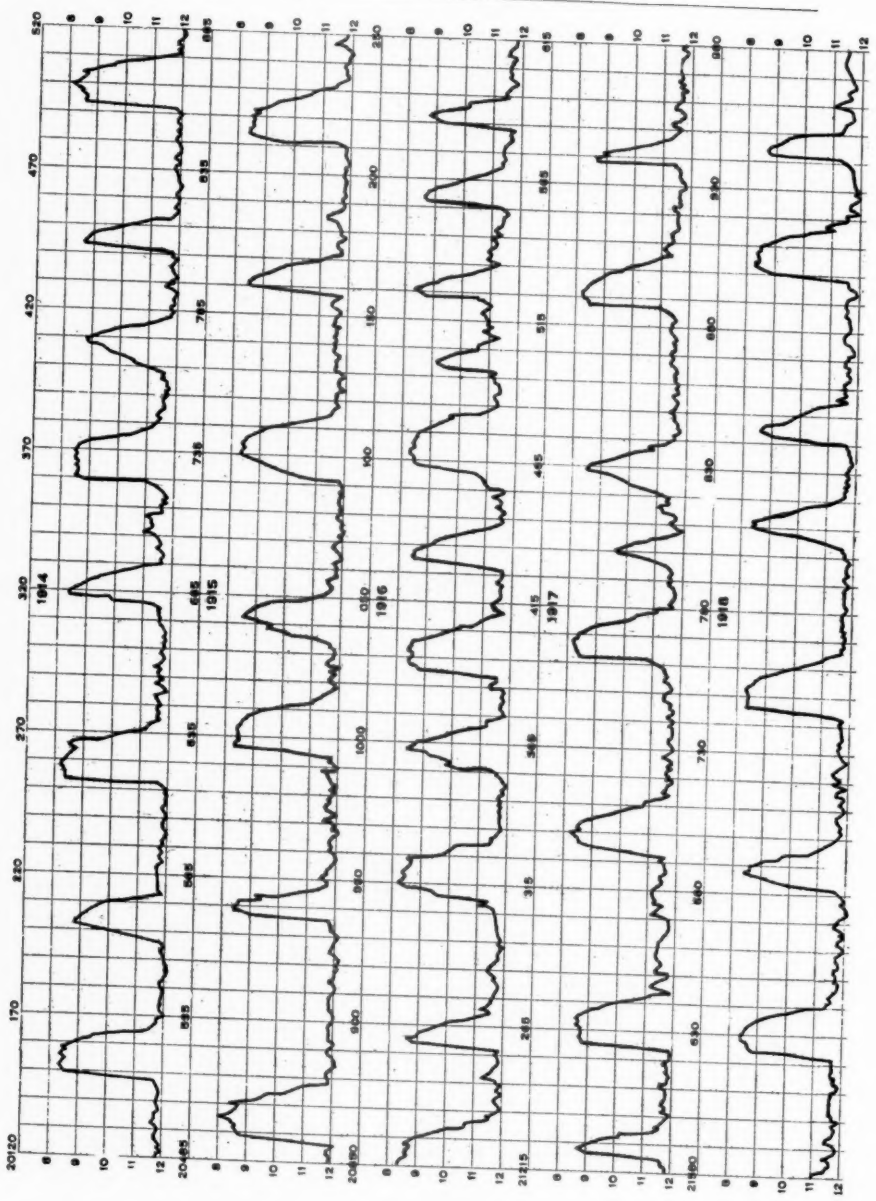
By LEON CAMPBELL.

The accompanying light curves* of SS Cygni, 213843, have been compiled at the Harvard Observatory from all available observations made during the years 1914 to 1922, inclusive. The principal sources are the American and British Variable Star Associations. Several thousands of observations are included, the points, in general, being daily means, except when the variable was rising rapidly.

The period is, on the average, about fifty days, but an inspection of the curve indicates that there have been wide divergences from this value. Curves of several different types appear, some of them exhibiting a rapid rise to maximum, with varying breadths, while others rise slowly. The descents are usually of nearly uniform rapidity.

Apparently no maximum has been missed by the observers during this interval of nine years; and observations more or less continuous have been made since the discovery of the variable in 1896. Because of the importance of this peculiar and infrequent type of variation, the light curve deserves careful and extensive analysis.

*See next page.


1914
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1918

THE LIGHT CURVES OF SS CYGNI 1914-1922,
Prepared by Leon Campbell of Harvard College Observatory.

THE GALACTIC SYSTEM.*

By HARLOW SHAPLEY.

Throughout the known sidereal universe there is, among material bodies, an obvious associative tendency, which we see well illustrated in meteor showers, in satellite and planetary systems, in binary stars, and in larger stellar groups such as the Pleiades. These various products of gravitational ordering are clearly but parts of still greater systems, and one of the most fascinating of astronomical studies is to attempt to seek out the structure of an all-inclusive sidereal organisation.

It is proposed in this communication to discuss the structure and extent of the sidereal system as indicated by recent studies of stellar clusters and variable stars. My own observational investigations of these objects, and the deductions based upon them, have been mainly published in Contributions and Communications of the Mount Wilson Observatory[1] from 1914 to 1918. The present discussion is made in the light of criticisms and numerous tests to which the conclusions have been subjected during the past four or five years.

It appears that we have three principal types of celestial objects to consider—the diffuse nebulæ, the stars, and the nebulæ of the spiral family. The first two are generally thought to be related as parent and offspring. The stars, having formed, as we think, out of nebulous pre-stellar states, are, apparently, largely organised into groups, a common, possibly prevailing, form being the globular cluster. It is from combinations of these clusters that I believe our galactic system has developed.[2] From the work on clusters there can be little doubt of the enormous mass and dimensions of the galactic system as compared with clusters and nebulæ. Its flat form and heterogeneity, its content of numerous fragmentary systems (open clusters, wide binaries, spectrally-similar groups) of apparently different ages and separate origins, and its control over the motions of the clusters and near-by spirals, have led me for some years to advocate the hypothesis that the Galaxy is a growing composite of disintegrating minor systems. The Galaxy appears to include all the common sidereal types, with the probable exception of most nebulæ of the spiral family. But the latter are apparently not stellar in composition, nor galactic in size. I think present evidence favours, but does not establish, the hypothesis that typical spiral nebulæ represent a sidereal evolution not directly connected with that of stars.

The foregoing paragraph may serve as a brief outline. Some of the details may now be considered, but, before proceeding with the discus-

*Adapted from an Address given before the British Astronomical Association on May 31, 1922. Reprinted from *Nature*, October 21 and 28, 1922.

sion, I should like to point out that the proposed interpretations involve the following somewhat fundamental assumptions, if we choose to call them assumptions: (1) that gravitation directs the organisation and motions of celestial bodies; (2) that the physical laws we know are equally valid in all parts of the space with which we are familiar; (3) that the Russell-Eddington theory of stellar evolution is correct in its general features.

Certainly these three are not serious restrictions. On the first I need make no comment here. The second is the basis of our belief in the general uniformity of conditions throughout the stellar system. It insists that our stellar neighbourhood is not operated by local laws. It is a highly reasonable but necessary assumption before we can safely compare the luminosities and other properties of stars near the sun with those of stars in distant parts of the galactic system. The third assumption, the Russell-Eddington theory, is not necessary for my conclusions concerning the dimensions of the galactic system, but is essential in putting together the general scheme, and also in trying to interpret some anomalies of the spiral nebulæ. We might call the evolutionary scheme the Lane-Lockyer-Ritter-Sampson-Emden-Schwarzchild-Hertzsprung-Russell-Eddington-Jeans-Eggert theory, but Russell and Eddington have been the most important contributors to the theory in its present form.

Concerning Star Clusters.

Clusters of stars can be placed in two fairly distinct categories, the globular cluster, of which nearly ninety are now known, and the open or loose cluster, of which there are several hundred.

Most globular clusters (but not quite all) appear to be remarkably alike in general structure. Compared with naked-eye objects they are extremely remote; hence their stars, though apparently very faint, are actually of high intrinsic luminosity. Few stars in globular clusters are brighter than the eleventh apparent magnitude. Each globular cluster contains some tens of thousands of these intrinsic bright stars, and possibly a far greater number of dwarfs which at present are beyond the reach of our telescopes. Of high importance is the fact that the cluster stars appear to be remarkably similar to the stars in the solar neighbourhood in spectral type, colour, variability, and other properties, notwithstanding the much higher stellar density near the centres of globular clusters.

Open clusters are of great variety. They range in brightness from naked-eye systems, such as the Hyades, to small, dim groupings that may be nothing more than chance aggregations of faint Milky Way stars. Open clusters vary also in richness, in apparent and real dimensions, in stellar content. One property they have in common: they are all near the plane of the Milky Way. The distance of the average open cluster is smaller than that of globular clusters, but the determination

of distances for the former is generally subject to much uncertainty. This fact is due to variety of form and content, and to the absence from open clusters of peculiar types of highly luminous stars, which for globular clusters serve to determine positions in space.

The estimation of the distances of globular clusters, which has been the most important part of the work on the scale of the sidereal universe, must be based on the newer methods of measuring space. The various trigonometrical methods, when applied to globular clusters, so far give negative results, indicating only that the distances are very great. The various photometric methods that had to be developed for this problem involve a considerable amount of photometric, spectroscopic, and statistical detail when put on a quantitative basis, and cannot be fully described in this article.

The qualitative application of the photometric methods, however, is simple. For example, we need only assume that the brightest stars of a globular cluster have the same actual luminosity as the brightest stars in the solar neighbourhood, and we can readily compute the distance necessary to give them the apparent brightness that is measured.

If we admit the similarity of globular clusters, it is obvious that either the apparent magnitude or the apparent diameter can give us the distances of them all when once we have determined the distances of those nearer the earth. In practice the distances of the nearest clusters have been determined from studies of their variable stars, of their blue stars (spectral type B), and of their red giant stars; and checked by spectroscopically-determined absolute magnitudes and by means of the relative diameters. All the methods agree in giving distances of the same order of magnitude. We thus find that the globular clusters range in distance from seven thousand parsecs to values nearly ten times as great. Their diameters are of the order of a hundred parsecs. Their brightest stars are a thousand times as bright as the sun.

The Structure of the Galaxy.

The result of most interest that comes out of this photometric investigation is the enormous dimensions of the super-system of globular clusters and of the Galaxy. Once the positions in space are determined, it becomes clear, as had already been suspected from an inspection of the apparent distribution of clusters in the sky, that globular clusters are a part of the Milky Way system. They are associated physically with the system of stars, nebulæ, and open clusters which is more or less symmetrically arranged with respect to the equatorial plane of the Galaxy. In measuring the distances of the remotest globular clusters, therefore, we are but measuring the depth of our own galactic system. That the Milky Way itself extends to distances as great as those indicated by the clusters is shown by the presence within it of highly luminous types of stars with apparent magnitude 15 and fainter.

It has been known for many years that globular clusters are not

uniformly distributed in galactic longitude. They are most numerous along the edges of the southern Milky Way. That one-sided distribution is now recognised as an indication of the sun's very eccentric position in the galactic system. In this same southern part of the sky we find the densest galactic star-clouds and the greatest frequency of faint novæ and of other types of distant objects, which is but further evidence of the greater depth of the galactic system in the direction of Sagittarius. Also in that general direction are some obstructing dark nebulæ, which may be wholly responsible for a peculiar phenomenon in the distribution of distant globular clusters, that is, in their seeming absence from regions very close to the galactic plane. If the obstructing material were removed, we might see, near the galactic plane, clouds of faint Milky Way stars still more dazzling than those observed, and globular clusters still more distant than those now known, and hence find that the greatest diameter of the galactic system is even larger than the value now assigned—approximately 100,000 parsecs.

The observable dynamical relations within and without the Milky Way are suggestive of its origin. No open clusters have yet been found outside the Milky Way region, but hundreds are known within. North and south of the galactic plane the globular clusters are equal in number, and their distances from the plane are much smaller than the greatest diameter of the system. Their velocities, so far as now known, are high. Many are approaching the galactic plane with speeds that soon must bring them to it. Their present positions and motions make orbital motion around the Milky Way improbable. From the present evidence as to mass, velocity, and distribution, there can be little doubt but that the known globular clusters pass to and fro through the star fields of the galactic system, notwithstanding their observed avoidance, apparent or temporary, at the present time. Every passage must reduce the velocity and alter the form. The hypothesis that these globular clusters are being diverted by degrees into galactic regions, and gradually robbed of their stars, is upheld by observation and is not opposed by present dynamical theory. Although we see few intermediates between the globular and the more typical open clusters, many of the characteristics of the open groups strongly support the suggestion that they are the remnants of globular clusters or of other systems that have been assimilated by the incomparably more massive galactic assemblage. Nearly a dozen "moving" clusters, comprising thousands of members, are recognised among the stars within seven hundred light-years of the sun.

Two important theoretical researches by Jeans are of much significance in this view of galactic structure: (i.) the form resulting from the interpenetration of two clusters,[8] and (ii.) the necessity, in accounting for the present orbits of long-period binaries, of assuming their former existence in a much more compact stellar field than now exists in the

solar neighbourhood.[4] The high stellar frequency near the centre of a globular cluster would certainly supply conditions favourable for modifying orbits, and it also might aid in explaining the origin of long-period binaries which is not otherwise accounted for satisfactorily.

The determination, with the aid of clusters, of dimensions for the galactic system much larger than had been clearly indicated by studies of the nearer galactic stars, led to a further examination of the stellar distribution in the solar neighbourhood. The hypothesis that the galactic system, as we now know it, has developed from the combination of minor groups, suggests that the brighter stars near the sun may to a large extent be members of a local system that is imbedded in and moving through the general star fields of the Milky Way. This condition actually appears to be the case, and hence the results on galactic dimensions, from clusters and from the nearer stars, do not contradict. Stars of spectral type B down to the sixth apparent magnitude seem to be almost exclusively members of a local cluster or cloud. Brighter stars of Class A are also affiliated with the same system.[5] Probably all the other types are to some extent involved,[6] but for them the disentanglement of local system and galactic field is more difficult.

Quite analogous to the phenomenon of the Milky Way, the projection on the sky of the faint stars along the central plane of this local cloud gives rise to a sort of secondary Galaxy,[7] the brighter stars of which coincide roughly with the Herschel-Gould belt. The distribution of the B stars indicates that the dimensions of the local system are large compared with those of a globular cluster: the local system is also more oblate. I believe it can be better compared in dimensions, and possibly in form, with the Magellanic Clouds or with the distinctly delimited small star clouds of the Milky Way. The various phenomena of star streaming are undoubtedly connected with the motions of and within the local system. Probably a number of our brighter "moving" clusters should be considered sub-systems in the local cloud, rather than independent systems which for the time being are near at hand.

Objections to Proposed Scale of the Galaxy

Although the new values of galactic dimensions have been widely accepted by astronomers, at least qualitatively, they have been openly challenged by some. Without questioning my values (which may indeed have been unknown to him), Professor Charlier published a few years ago provisional cluster distances that are of a wholly different order of magnitude from those I derive.[8] He had, in effect, affiliated the globular clusters with the local system of B stars. I believe he has now accepted the larger values of the distances.[9]

An extensive critical examination of my methods and results has been made by Professor Curtis. His discussion and my reply have been published together in Bulletin No. 11 of the National Research Council.

Dr. Schouten has attempted to derive the distances of clusters by assuming that the frequency of absolute magnitude (the luminosity-curve) is the same in globular clusters and in the neighbourhood of the sun.[10] The method is questionable for several reasons: (1) All spectral types are lumped together by Schouten regardless of our present knowledge of the peculiar relation of type and luminosity in the globular clusters. (2) The giant-dwarf phenomenon is essentially ignored in the method. (3) The observed luminosity-curves in globular clusters do not conform with the law assumed.[11] (4) It is certainly improbable that the stage of evolution in any given cluster is closely comparable with the average of the many stages represented by the heterogeneous mixture around the sun. (5) As applied, the luminosity-curve method involves dangerous extrapolation, for we know the frequency of magnitudes for only the very brightest stars in clusters.[12]

Using the necessarily fragmentary luminosity-curves for a few clusters, Schouten finds distances averaging about one-eighth the values I have computed.

Recently, Kapteyn and van Rhijn published a valuable paper on the proper motions of Cepheid variable stars of the short-period subtype.[13] It is generally accepted that Cepheid variables of long period are giant stars; and from the simultaneous occurrence of the long-period and short-period Cepheids in globular clusters,[14] I have assumed of course that the short-period Cepheids, which occur most frequently in clusters and serve in one of the methods of estimating the distances, are also giant stars. Kapteyn and van Rhijn, on the other hand, have computed, from the large values of the proper motion, small distances for the cluster-type variables, and therefore low luminosities. They conclude that Cepheid variables of this sub-type may be dwarfs, both near the sun and in clusters; and, by assuming that the long-period Cepheid variables in clusters are abnormalities and the short-period Cepheids are normal, they assert that the clusters may be at less than one-seventh the distances I place them. But Kapteyn and van Rhijn appear to have overlooked the decisive factor that the known radial velocities of these short-period Cepheids are remarkably high[15] (much too high, apparently, for the application of the method they use[16]); and therefore that the large proper motions they deduce and the wide distribution in galactic latitude are almost certainly the result of exceptionally high velocities in space, rather than an indication of nearness and low luminosity.* Similarly, the long-period variables of spectral type M are giants at maximum, are widely distributed in galactic latitude, and have high space velocities.

*See Harvard Circular 237, recently issued, in which the Groningen material is analyzed and much other evidence is brought forward in support of the larger dimensions of the Galaxy. The new trigonometric parallaxes of Cepheids are in good agreement with values based on the period-luminosity curve. See also Harvard Bulletins 773 and 778 for absolute magnitude of a cluster-type Cepheid, RZ Cephei.

As Dr. Crommelin has hinted recently in *The Observatory*,[17] a sufficient answer to those who would reduce the distances of clusters to one-fifth or one-tenth the values proposed, is that apparently they do not consider fully the dire consequences of such reduction on a vast body of other astronomical data that is now generally accepted. If the distances I give are not greatly reduced or increased these troubles do not arise; all that we know of the colours, spectra, magnitudes, and motions in the clusters, and of the clusters, then fits in well with our general stock of astronomical fact and theory.

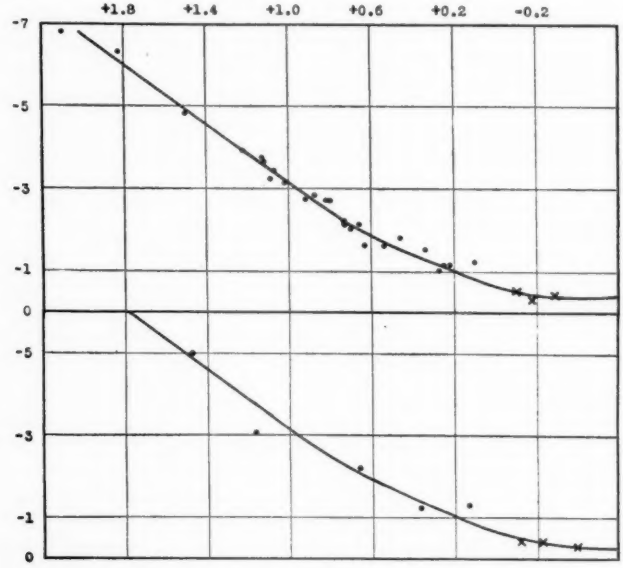


FIGURE 1. The adopted period-luminosity curve for Cepheid variables, and observations for the small Magellanic Cloud (above) and the globular cluster ω Centauri (below). Ordinates are absolute visual magnitudes; abscissas are logarithms of the period. New material for the Small Magellanic Cloud is represented by the three crosses in the upper figure. (From Harvard Circular 237, August 1922.)

Before we knew much about the character of stars in clusters we were not restricted by observation or theory from placing the clusters at whatever distances we liked. But now, if we alter the present distances by the amount Curtis, Schouten, and Kapteyn and van Rhijn suggest, we immediately set up peculiarities and discordances in great numbers. For example, among other difficulties evoked by such changes, we would seriously question the general applicability of the spectroscopic method of determining luminosities and distances;[18] we would introduce confusion into Russell's and Eddington's theories

which now so happily conform with physical laws and observational results, in clusters as well as outside; we would overthrow the period-luminosity law of Cepheid variation. Sooner or later it may be necessary to divide or multiply by 1.5 (Dr. Crommelin suggests 2) the distances I have computed for the clusters; any larger factor will entail alterations elsewhere that now appear improbably large.

It seems to me that a better line of attack on the proposed scale of the Galaxy would be to question the apparent magnitudes rather than the absolute luminosities. The latter, as we have seen, are supported by too much evidence of a varied nature to yield easily. Moreover, the values of the absolute luminosities for the stars in clusters come within the range of our usual experience, whereas the apparent magnitudes (and distances) of cluster stars are quite different from those of stars we ordinarily treat.

Since the computed distances depend equally on absolute and apparent magnitudes, they could be considerably changed, if the apparent magnitudes are widely wrong, without disturbing present ideas about stellar luminosity. The fundamental work on magnitude standards at Mount Wilson, Harvard, Greenwich, and elsewhere supply, however, a basis of unquestioned value for the cluster work. The apparent magnitudes I have observed in clusters cannot, I believe, be far wrong;[19] but has the light of these distant stars been reduced in transit so that the apparent magnitudes as observed are not a true index of distance? This question should be kept in mind, but the following points seem to show that the observed apparent magnitudes do not differ seriously from true apparent values because of a hypothecated diminution of light during its passage through space:

(1) The absence of measurable differential light scattering in space, which would appear as a dependence of star-colour on distance.

(2) The apparent restriction of known obstructing matter to regions near the planes of the local cloud and the Galaxy;[20] the globular clusters we study are practically all outside these regions.

(3) The diameter-magnitude correlation for globular clusters, which shows, almost without exception, that the globular clusters with large angular diameters are bright, and that the faint globular clusters are of small angular diameter.[21]

(4) The absence of observable proper motion for clusters, notwithstanding large space velocities.

Incidental Results.

In the course of the investigation on the scale of the galactic system a number of incidental contributions of general scientific interest have been made.

I. The great distances of globular clusters provide a much more sensitive test of the degree of selective scattering of light in space than was formerly available from the studies of the colour of near-by stars. Results from many clusters, including the most remote, agree in show-

ing no certainly measurable effect of distance on colour. We conclude that much less than one per cent. of the starlight is scattered while travelling for one thousand years through space.[22] This result, which does not hold of course for some restricted nebulous regions, indicates the extreme vacuity of interstellar space.

II. This absence of a measurable effect of distance on colour contributes an additional fact of some interest with regard to the nature of light. It is direct observational evidence that the amplitude of the light pulses of different wave lengths has suffered no differential alteration while travelling for more than 100,000 years. The age of this incoming stellar radiation, compared with that of the radiation used in laboratory experiments, is uncommonly impressive.

III. In a more definitely quantitative manner we can again use the base line in space and in time afforded by the globular clusters to derive another property of radiation. The times of maxima of several short-period Cepheid variable stars in the globular cluster Messier 5 (distance 12,000 parsecs) have been measured concurrently with blue and yellow light. Within the errors of observation, no difference for the two colours is found in the time of these stellar outbursts.[23] That is, in travelling for 40,000 years, radiation that differs in wave length by 20 per cent. differs in time of arrival at the earth by less than two minutes, if at all. This is equivalent to a difference of less than one millimetre in a distance of 5000 miles. Stated otherwise, blue and yellow light travel with the same velocity with an uncertainty of less than one part in ten thousand million.

IV. In still another way can we make valuable use of the long base line provided by the remote clusters. A considerable analysis of the distribution of spectral types among the giant stars shows no measurable difference for near and distant globular clusters. This strongly suggest, of course, that the nearest systems are not appreciably more advanced in their evolution; but because of the finite velocity of light and the great differences in distance, they are, in our records, nearly 200,000 years older than the farthest ones. With these globular clusters we can, in effect, examine the process of stellar evolution throughout an interval of 2000 centuries. We find no evidence of change in that interval of time.[24]

Now Eddington has shown that very conspicuous advances in the evolution of a giant star would occur in less than 50,000 years, if gravitation is the main source of radiant energy.[25] We are led to believe, therefore, that gravitational contraction is not the main source of the energy that maintains the radiation of stars; it appears that the energy must come from the atom, and probably is released in the course of the transformation of the chemical elements.

The evidence for a slow stellar evolution is strongly supported, I believe, by the existence of stars, which are still in their giant stage, in the open clusters that move along the galactic plane. Dimensions now

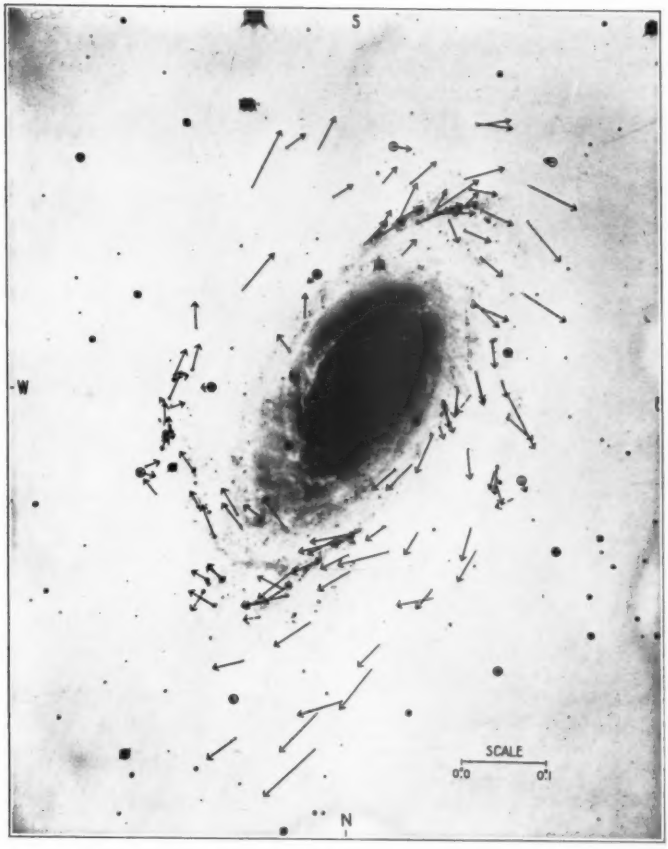


FIGURE 2. INTERNAL MOTIONS IN MESSIER 81.

The arrows indicate the direction and magnitude of the mean annual motions. Ther scale (0".1) is indicated in the illustration. The scale of the nebula is 1350 times smaller. The comparison stars are inclosed in circles. (*Astrophysical Journal* **54**, 347, 1921.)

assigned the galactic system are so large that a single oscillation of a cluster must require millions of years. In fact, a greater space scale for the Galaxy practically makes necessary a long time scale and a slow stellar development. The extreme slowness with which the periods of Cepheid variables change, as Eddington has pointed out, also demands the new source of energy.[26]

V. In this connexion it may be observed that the question of the dependence of the speed of evolution on mass for a giant star is probably answered observationally by the regularly occurring phenomenon in clusters of increasing blueness with decreasing brightness. The well-known investigations by Eddington and Jeans indicate that high absolute brightness is associated with great mass, but the theory is not definite in regard to the relative rates of evolution for different masses. From the clusters we would conclude that the greater the mass the slower the development.[27]

VI. The most luminous stars in globular clusters, the spectra of which, by the way, appear to have the "*c*-characteristics" which are associated with extraordinary brightness, are more concentrated to the centre than fainter stars. This condition independently supports the inference that the most luminous are the most massive stars.

VII. The remotest object for which a definite estimate of distance has yet been made is one of these faint globular clusters, N. G. C. 7006, for which a value of about 65,000 parsecs (more than 200,000 light-years) has been obtained, and checked by three or four different photometric methods. The most recent determination of its distance involved the discovery and study with the 100-inch reflector at Mount Wilson of Cepheid variables of the 19th apparent magnitude—the faintest periodic variable stars on record. It is likely that more remote objects, with distances as yet unmeasured, have been seen or photographed—possibly among the faintest spiral nebulæ or among the faint stars in the Milky Way.

VIII. A recent investigation of Cepheid variable stars in the Small Magellanic Cloud has shown that the very faintest variables have periods of less than one day.[28] This result, which permits the direct extension of the period-luminosity law to the short-period type of Cepheid, as shown in Figure 1, is further evidence of the high absolute luminosity of the kind of Cepheid variable which is most frequent in globular clusters.

IX. The proposal of a larger scale for the galactic system brings us face to face with the "island universe" theory of spiral nebulæ, which, with varying success, has for many years maintained that the spirals are other "universes" of stars—that they are galaxies comparable with our own, and that our Galaxy, seen from a sufficient distance, would appear as a spiral nebula. A theory of "comparable galaxies" immediately becomes very difficult to maintain along with the larger dimensions of the galactic system. In a paper published three years

ago I discussed at some length this problem of external galaxies.[29] The conclusion reached at that time, that the nebulæ of the spiral family are probably neither galactic in size nor stellar in composition, has been strengthened rather than weakened by subsequent investigations, particularly by van Maanen's remarkable work on the motions in the brighter spirals.[30] His results for Messier 81 are illustrated in Figure 2 (Plate XIX).

X. Since the brighter spiral nebulæ, according to the present view, are probably within the boundaries of our galactic system, it may be that the novæ occurring so frequently in the Andromeda nebula represent the encounter of this enormous, rapidly moving object with galactic stars. The suggestion is in harmony with the Seeliger-Monck hypothesis of the cause of ordinary novæ; and, moreover, it is in line with the only hypothesis that has yet been advanced to account for the peculiar irregular variable stars in the diffuse nebulæ, such as those in Orion.[31] This interpretation of the variables of the relatively near Orion nebula would certainly be of significance for historical geology, since disturbances of our sun, much less serious in character than those observed for novæ and for the Orion variables, would be of paramount importance in matters pertaining to terrestrial climates and organisms.[32]

XI. Conversely, we can use the geological records to show that the radiating equilibrium of the sun probably has been uncommonly stable compared with that of many stars. The investigation at Harvard under Professor Bailey's direction of the frequency of galactic novæ brought out the remarkable result that at least fifteen novæ brighter than the tenth magnitude at maximum, have appeared every year during the last three decades.[33] If a frequency of even one-fifth that amount has been maintained throughout the hundreds of millions of years of approximately constant solar radiation (shown by the geological records), more novæ have occurred than there are known stars. Our sun, however, which has certainly escaped not only disasters of this kind but even much less serious disturbances, apparently moves in an uneventful region of space.

XII. The attractive and somewhat futile speculations on the probability of the occurrence of protoplasmic life and its slow evolution elsewhere in the sidereal system must, of course, take account of the frequency of these calamitous stellar outbursts that we call novæ.

In connexion with this attempt at a partial interpretation of galactic structure it might be well to emphasise the following points.

(1) Many of the fundamental laws and assumptions of physics are involved in this sidereal superstructure, so that developments in thought or observation, which hereafter greatly affect these laws and customary assumptions, may at the same time seriously disturb existing conceptions of the sidereal system.

(2) The complete elucidation of the source of stellar energy may

bring with it modifications both in our views of the evolution of stars and in our assumption of the importance of gravitational organisation of stellar bodies.

(3) The question of the obstruction of light in space is not in a satisfactory condition, and the nature of the radiation of the diffuse nebulæ is little understood; we have essentially no information concerning the pre-giant stage of stars and its relation to the diffuse nebulæ, and the dust and gases in space.

(4) Cepheid variables, though comparable with each other, may possibly be sufficiently different from other stars that we cannot use their speed of evolution as a quantitative measure of the speed of evolution for all stars.

For the present I take little heed of these warnings, and merely record them as examples of underlying uncertainties. They serve to remind us that the conclusions are based not only on favourable observations and theory, but also on the absence (for the time being) of seriously unfavourable data.

REFERENCES.

[1] Cf. *Astroph. Jour.*, Proc. Nat. Sci., Pub. Astron. Soc. Pac., 1915-1921, and *Scientia*, 1919-1920.

[2] *Pub. Ast. Soc. Pac.*, February 1918; *Mt. W. Contr.*, 157.

[3] *Mon. Not. R. A. S.*, 76, p. 563.

[4] *Scientia*, January 1922.

[5] *Harv. Circ.*, 229.

[6] Van de Linde, *Thesis*, Rotterdam, 1921.

[7] *Scientia*, March 1920.

[8] *Lund Meddelanden*, Series 2, No. 19.

[9] *Bul. Nat. Research Council*, No. 11, p. 174.

[10] *Proc. Acad. Sci. Amsterdam*, 20, p. 1108; 21, p. 36.

[11] *Mt. W. Contr.* 155, and 175, p. 11.

[12] I first tried out the method six years ago (*Mt. W. Contr.* 116, p. 81), but abandoned it as wholly unsuited to the brighter stars in globular clusters. The Kapteyn luminosity curves for separate spectral types, however, may be of high value.

[13] *Bul. Ast. Inst. Neth.*, No. 8.

[14] Kapteyn and van Rhijn state that eight Cepheids of long period are known in two globular clusters. In my paper from which they get their data (*Mt. W. Contr.* 151) I show that twelve long-period Cepheids occur in the five globular clusters Messier 3, 5, 13, 15, and Omega Centauri. Four of these clusters contain also large numbers of short-period Cepheids only one or two magnitudes fainter than the long-period Cepheids. Unpublished results obtained at Harvard show that long-period Cepheids occur in other globular clusters.

[15] *Mt. W. Contr.* 153, *Mt. W. An. Rep.* for 1918, and elsewhere.

[16] Russell, *Astroph. Jour.* 54, p. 140.

[17] *Observatory*, May 1922.

[18] *Bul. Nat. Research Council*, No. 11, pp. 184, 190.

[19] The photovisual magnitudes for Messier 11, however, are probably affected by a serious scale error; the color indices do not agree with the spectra subsequently determined (*Mt. W. Contr.* 120 and 228).

[20] *Mt. W. Commun.* 62, p. 6; cf. also Hubble, *Mt. W. An. Rep.* for 1921, p. 251.

[21] *Mt. W. Contr.* 115, p. 12, 152, p. 10, and 161, p. 13.

[22] *Mt. W. Contr.* 156, p. 5.

[23] *Harv. Bul.* 763.

[24] *Mt. W. Contr.* 156, p. 5, and 157, p. 14.

[25] *Zeits. für Physik*, 7, p. 390.

[26] *Mon. Not. R. A. S.* 79, p. 19.

[27] This conclusion may not hold for close double stars, as certain results from eclipsing binaries are not in full agreement; the less dense, dark companion is believed to be, frequently, less massive and also less developed than its primary.

[28] *Harv. Bul.* 765; *Proc. Nat. Acad. Sci.* 8, p. 69.

[29] *Pub. Ast. Soc. Pac.*, October 1919.

[30] *Mt. W. Contr.* 213 and 214.

[31] *Mt. W. Contr.* 156, p. 12; cf. Graff, *Ast. Nach.* 5133.

[32] *Jour. of Geol.* 29, p. 502.

[33] The annual number brighter than the tenth magnitude actually exceeds forty, according to Bailey's data. *Pub. Am. Ast. Soc.* 4, p. 248.

TRIGONOMETRIC PARALLAXES OF THE BRIGHTEST STARS.

By S. A. MITCHELL, C. P. OLIVIER and H. L. ALDEN.

In view of the great interest attaching to the parallaxes of the brightest stars it has seemed advisable to publish separately the values of all stars brighter than magnitude 3.0 derived by photography at the Leander McCormick Observatory. In the past, large errors have crept into the parallaxes of the very brightest of the stars on account of the great differences in magnitude from stars serving as comparison stars. By visual methods it has been utterly impossible to make a proper reduction in brightness.

At the McCormick Observatory the magnitude of the average comparison star is of the tenth visual magnitude. By a method described in POPULAR ASTRONOMY, **28**, 517, 1920, it has been possible to reduce even Sirius in brightness so that it shall have on the photographic plate a diameter equivalent to those of stars of the tenth magnitude. For this reason it is thought that no systematic errors are introduced into the McCormick parallaxes of these stars on account of their brightness. The average probable error of the following 63 stars is 0″.009 which is the same in size as the probable error of nearly 600 stars already completed at the McCormick Observatory.

The value given in the table is the relative parallax referred to the comparison stars of tenth magnitude. To obtain the absolute parallax, 0″.005 should be added to the relative value. Absolute magnitudes are given for all of the stars which have not a negative value of the parallax.

Star	R. A. 1900 h	m	Magn.	Spect.	Relative Parallax		Absolute Magn.	Measurer
β Cassiopeiae	0	3	2.4	F5	+″058	± ″011	+1.4	M
α Cassiopeiae	0	34	2.5	K0	+.025	.005	—0.1	M
γ Cassiopeiae	0	50	2.2	B0p	+.033	.008	+0.1	Ol
β Andromedae	1	4	2.4	Ma	+.058	.008	+1.4	Ol
β Arietis	1	49	2.7	A5	+.091	.012	+2.6	Ol
γ¹ Andromedae	1	57	2.3	K0	+.013	.008	—1.4	A
α Ceti	2	57	2.8	Ma	+.017	.010	—0.5	A
α Persei	3	17	1.9	F5	+.013	.010	—1.8	A
η Tauri	3	41	3.0	B5p	+.003	.011	—2.5	A
ε Persei	3	51	3.0	B1	—.013	.011		A
α Tauri	4	30	1.1	K5	+.035	.008	—0.9	M
β Eridani	5	2	2.9	A3	+.049	.009	+1.6	Ol
α Aurigae	5	9	0.2	G0	+.078	.008	—0.2	A
β Orionis	5	9	0.3	B8p	+.002	.009	—5.5	M
γ Orionis	5	19	1.7	B2	+.024	.007	—1.0	A
β Tauri	5	20	1.8	B8	+.030	.008	—0.5	A
β Leporis	5	24	3.0	G0	—.001	.005		Ol
δ Orionis	5	26	2.5	B0	+.006	.010	—2.3	A
α Leporis	5	28	2.7	F0	+.009	.008	—1.6	M
ζ Tauri	5	31	3.0	B3p	—.006	.008		Ol
α Orionis	5	49	0.9	Ma	+.013	.006	—2.8	A
β Aurigae	5	52	2.1	A0p	+.026	.009	—0.4	A
β Canis Maj.	6	18	2.0	B1	+.007	.010	—2.6	M
γ Geminorum	6	31	1.9	A0	+.028	.006	—0.5	A
α Canis Maj.	6	40	—1.6	A0	+.354	.008	+1.1	M
α¹ Geminorum	7	28	2.8	A0	+.086	.007	+2.6	A
α² Geminorum	7	28	2.0	A0	+.067	.010	+1.3	A
α Canis Min.	7	34	0.5	F5	+.309	.007	+3.0	M
β Geminorum	7	39	1.2	K0	+.107	.012	+1.4	A
ρ Puppis	8	3	2.9	F5	+.026	.008	+0.4	Ol
α Leonis	10	3	1.3	B8	+.059	.013	+0.3	A
γ¹ Leonis	10	14	2.6	K0	—.002	.009		M
δ Leonis	11	8	2.6	A3	+.073	.008	+2.1	A
γ Ursae Maj.	11	48	2.5	A0	—.002	.007		A
ξ¹ Ursae Maj.	13	19	2.4	A2p	+.046	.010	+0.9	M
α Virginis	13	19	1.2	B2	+.009	.010	—3.1	A
η Ursae Maj.	13	43	1.9	B3	+.001	.011	—4.2	A
α Bootis	14	11	0.2	K0	+.076	.008	—0.3	A
α Coronae	15	30	2.3	A0	+.056	.010	+1.2	Ol
α Serpentis	15	39	2.7	K0	+.038	.008	+0.9	M
δ Ophiuchi	16	9	3.0	Ma	+.040	.010	+1.3	D
η Draconis	16	22	2.9	G5	+.002	.010	—2.9	A
α Scorpii	16	23	1.2	Ma	+.025	.007	—1.4	A
ζ Herculis	16	37	3.0	G0	+.115	.008	+3.4	A
β Draconis	17	28	3.0	G0	—.015	.007		A
α Ophiuchi	17	30	2.1	A5	+.042	.009	+0.5	A
β Ophiuchi	17	38	2.9	K0	+.021	.010	0.0	M
γ Draconis	17	54	2.4	K5	.000	.006	—4.1	Ol
α Lyrae	18	33	0.1	A0	+.131	.006	+0.7	A
ζ Sagittarii	18	56	2.7	A2	+.018	.008	—0.5	Ol

Star	R. A. 1900 h	m	Magn. and Spect.		Relative Parallax		Absolute Magn.	Measurer
ξ Aquilae	19	1	3.0	A	+″027	± ″010	+0.6	Ol
π Sagittarii	19	3	3.0	F4p	+.012	.012	—0.8	Ol
γ Aquilae	19	41	2.8	K2	+.029	.011	+0.5	A
δ Cygni	19	41	3.0	A	+.024	.013	+0.3	A
α Aquilae	19	45	0.9	A5	+.218	.007	+2.6	M
γ Cygni	20	18	2.3	G0	—.003	.010		H
α Cygni	20	38	1.3	A2	+.002	.005	—4.5	A
ε Cygni	20	42	2.6	G7	+.039	.008	+0.8	M
α Cephei	21	16	2.6	A5	+.091	.008	+2.5	Ol
ε Pegasi	21	39	2.5	K0	+.017	.008	—0.8	Ol
δ Capricorni	21	41	3.0	A5	+.110	.012	+3.3	H
β Pegasi	22	58	2.6	Mb	—.005	.006		Ol
α Pegasi	22	59	2.6	A	+.012	.011	—1.2	A

Leander McCormick Observatory,
University of Virginia.

AN APPRECIATION OF PROFESSOR E. E. BARNARD.

By MARY PROCTOR, F. R. A. S.

It was with the deepest regret I heard this afternoon (February 28), at the meeting of the British Astronomical Association, of the death of Professor E. E. Barnard. He was one of the kindest and most helpful friends, among the American astronomers I have known, and I owe him a great debt of gratitude for the many delightful treats he gave me at the Yerkes Observatory.

It was greatly owning to his guidance and encouragement that I kept on with my work along astronomical lines, and I have always cherished his valuable letters of advice. I shall do so now all the more, as the one who penned them is at rest from his labours. If anyone worked hard, one might almost say night and day, it was Professor Barnard, and it is an example which has had much to do with my own work.

Professor Barnard knew my father, and he often said to me: "Your father encouraged and helped me, and that is why I am anxious to help you."

He certainly did so, and though I have found the struggle very uphill at times, yet Professor Barnard always kept me from losing courage. That is why his loss means so much to me now.

ERRORS OF LATITUDE.

By R. H. TUCKER.

(Continued from page 183.)

The errors of graduation of the divided circles also enter our results. For our instrument, they have been found to average $\pm 0''.15$ for the mean of four divisions. For any number of observations of the same star, in the same position of the instrument, this is a constant or systematic error, either in declination or latitude results. It may be diminished by observing in both positions of the instrument, or by shifting the movable circle for each observation. It is, however, a question whether it is preferable to observe in the one position of the fixed circle, leaving the effect of graduation error a constant for each star; or to diminish the error by a varying amount, according to the number of observations, leaving it virtually accidental in character. The graduation error of the nadir reading is constant for the fixed circle in one position of the instrument, and the effect on latitude results is eliminated from the mean of both positions, when the fixed circle is used. There are, of course, no graduation errors to consider in zenith telescope work.

The probable error of a single observation of declination or latitude would include graduation, making it $\pm 0''.25$. For a group of twelve stars, on one night, the probable error of the mean should be $\pm 0''.08$. This probable error would not apply strictly to the continued observation of the same group of stars on successive nights, since the mean of the graduation errors would then be constant, or systematic.

Mathematicians are inclined to think that astronomical computers juggle the two classes of errors, and are not entirely definite in their use of the classification. But it is really not possible to define each class strictly for all conditions that arise. An error of accidental character, originally, may be systematic in its effect on certain results, and the contrary is equally true. An excellent illustration is the error of nadir readings.

The nadir observation is subject to the same sources of error as that of a star, circle reading, bisection and graduation. The first two are accidental in character, while the third is a constant for the fixed circle in the same position. Three sets of double bisections on the image of the wire are taken here, and the results should be precise, though subject to a possible systematic error. The probable error of a zenith point, with two or three nadirs, has been found to be $\pm 0''.15$ per night, and the mean latitude from any number of star observations

will be affected by this error, as systematic for the night. If we take any single observation of a star, the probable error of a latitude, with zenith error included, would be $\pm 0''.29$. For a group of twelve stars on one night, the error of the zenith point being constant, the probable error would be $\pm 0''.17$.

There is a corresponding error in the zenith point of zenith telescope observations. It is often taken for granted that the bubble reading of the delicate level gives the perfect horizontal. But every measurement is subject to human errors, and the level itself does not always give quick and precise response to small changes. The mean of the errors of a night gives what has been somewhat obscurely defined as the night error, and probably explains why probable errors computed from the results of separate nights generally exceed those computed from the individual observations of any one night.

Finally, in all latitude results the errors of declination must be considered. It is doubtful if many of our standard stars are really determined within an error of a tenth of a second of arc. There are periodic errors in our star systems depending on right ascension, and others depending on polar distance. For absolute latitudes any group of stars may have a mean error of $0''.1$ with respect to the system. We may set a fairly definite limit of precision for our meridian circle results at $\pm 0''.2$ per night, with allowance for all the errors thus far outlined.

The systematic error of the reading on the nadir may change for the same observer. It is likely to be different for different observers. Due to this effect, perhaps, or to other effects unknown, the probable errors of monthly mean results, and of yearly results are most likely to be larger than would be derived from the average errors of individual nights. Our probable error, computed in the discussion of $\phi - \phi_0$ from our own observations, is closely $\pm 0''.1$ per month. The same value is found for our quarterly results, two or three months in each. For annual results the probable error is $\pm 0''.07$, from the discussion of the observations of a quarter of a century. These are errors found for one observer, over a relatively long interval of time.

These figures not only indicate the existence of systematic errors that probably vary in amount, but they show that the limit of precision in work of this class has been defined, and that refinement of individual results and of mean results can not be carried much farther. Conclusions as to changes of latitude, both progressive and abrupt, should take into account the limits of precision possible in observations of this class.

In our annual ϕ_0, in which some periodic terms such as those due to errors of declination are well eliminated, no single yearly residual exceeds three times the probable error. In the differences between successive years, which should be a better test for abrupt changes than differential values for shorter intervals, there is no definite proof

of changes. The individual differences do not exceed twice the average, at any epoch since 1893.

In zenith telescope observations there are not as many sources of error. The combination of pairs of stars at equal distances north and south of the zenith eliminates the systematic bisection error, errors of flexure and errors of refraction. There are no microscopes to be read, with errors of runs, and there are no graduation errors. The zenith point is measured differentially at every observation, and there is no allowance to be made for the accidental and systematic errors of nadir readings. The only important sources of known accidental error are the bisection of the star, and the reading of the level. Stars of sharp images only are generally observed, and the total accidental error appears to be as small as that of bisection alone in meridian circle work. Four settings on a star are commonly made in modern practice, near the centre of the field. In the series of observations by the late C. L. Doolittle he assigned 0″.2 as the probable error of a single observation. Some observers claim errors of 0″.1 only. We may use 0″.15 as conforming to good modern work.

With sixteen pairs of stars per night, as customary in the schedule of the International stations, the mean result should have a probable error of $\pm$ 0″.03 per night. With eight nights a month, the probable error of a monthly mean should not much exceed $\pm$ 0″.01, and the yearly value should have a probable error of about $\pm$ 0″.003. Due, however, to the existence of systematic errors, not clearly defined as far as our information extends, the actual errors are larger.

With an expression for $\phi - \phi_0$, computed from the zenith telescope results for the past thirty years, individual observed values at tenths of a year have an average deviation of $\pm$ 0″.040 from the computed values. In computing $\phi - \phi_0$ at each thirty degrees of longitude, from the yearly x and y coördinates for Greenwich, as derived from all the stations, Albrecht gives average errors of from 0″.03 to 0″.045, for any individual station. His successor, Wanach, gives 0″.1 as the limit of errors which occur in the observed $\phi - \phi_0$. An error of this size should be expected to occur about once in two years, in a run of values at every tenth of a year.

Chandler was accustomed to rate as "eminently satisfactory" an agreement of between 0″.02 and 0″.03 between the separate results of several stations combined, and his theory, at various stages of his work.

Another test comes from the comparison of the observed values at intervals of 25.0 years. One advantage of this comparison is that no corrections need be computed and applied, and no assumptions need be made, other than that of uniform lengths for the annual and fourteen month periods. The average difference of observed $\phi - \phi_0$ at the two epochs is $\pm$ 0″.045, not allowing for an increase in the ob-

served mean values, which would very slightly diminish the residual differences.

If an expression for $\phi - \phi_0$ is derived from the observation at one station only, for an interval of one or two years, the separate monthly results will average to differ from the computed results by 0″.02. Since the computed expression has been directly influenced by the errors of observation, it will fit the observations more closely than a better expression would. The better expression will be derived from several stations, with the results of many years.

In computing the annual rate of ϕ_0 from all the International stations, the average difference of an annual ϕ_0 from its computed value was found to be $\pm$ 0″.023 with the respective rates applied. The probable error of an annual value of the latitude is at least six times the size of that which would be predicted from the accidental errors of observation alone. The probable error of monthly values is similarly at least three times the size of the predicted error. A sufficient analogy is found in the meridian circle work, where the monthly error is nearly twice as large as would be predicted from the accidental errors of single nights, and the yearly error is more than three times as large as would be predicted.

The existence of systematic errors is known and admitted in meridian circle work, for which the admission is not to be taken as any form of an apology, and the existence of unknown systematic errors in zenith telescope work follows, as the natural conclusion.

We are near the limits of precision in the latter, when dealing with units of the second decimal place; and the use of the third place is a superfluous refinement, except as a computing device to prevent the accumulation of residual errors that may influence the adoption of the last unit of the second place of decimals.

In astronomical computations, the third place is used in right ascensions, to preserve the significant unit of the second place. For meridian circle work, the first place only is really significant, in individual latitude results. The use of the second place is however justified, on the same grounds, providing it does not mislead those not familiar with the sources of observing errors.

The U. S. Coast Survey latitudes are commonly printed to the third place of decimals of seconds of arc. We do not question the precision of their accurate triangulation, which gives differential latitude results, but should guard against attaching too much significance to the ultimate decimal figure. The results are intended to represent the precision with two doubtful places of decimals, but usually the second figure from the right is reasonably certain. The closing error of a triangle is really an accidental error of observation. As the net of triangles is extended, each successive closing error, while it may be computed independently of those preceding, actually carries forward its share of the accumulated error into latitudes derived from the triangle which is the last of a series.

Another usage, which has perhaps been misleading, is the publication of the third place of decimals in some individual results for the International zenith telescope stations. One sometimes finds a summation of such results given to two places only, in the mean. This reverses the common usage, which permits of an additional decimal place in the mean of a goodly number of separate results, to express the increase in the precision of the mean. These usual computing devices are only injurious in their incorrect interpretation.

We see relatively vast decimal figures used in some modern parallax and proper-motion computations. The true interpretation must be made, both of purpose and method.

In dealing with any periodic term, the test of its validity may be made by comparing the differences between the observed results, and the results corrected for the periodic variation. If O — C is no smaller than the original residuals from the mean, the periodic correction has not improved the representation of the true result of observation by a simple mean. By as much as it is smaller, is our adoption of the periodic correction to be justified.

The average $\phi - \phi_0$ for any station is close to 0".12, at tenths of a year.

When the derived expression for twenty-five years is compared with the observed values, assembled in their appropriate group means, the O — C is less than four per cent of the size of these observed values.

When individual observed values are compared with the same expression, the average O — C is one third the size of the observed $\phi - \phi_0$. Since the full expression has ample proof, the average deviations in this case appear to be due to the errors of the individual observed results. The full expression can be derived with precision without applying individual corrections. Thus yearly means have the corrections for the annual term eliminated, and means of any multiple of the longer term have the corrections for this term eliminated. Using a full interval of 25 years, with results at each tenth of a year, the corrections for both terms are eliminated in the means.

This is true whether the radii of revolution of the two periodic terms are constant or not. This last point is continually arising, in the discussion of latitude variation. Deviations of observation from a mean formula are due either to errors of observation, or to variations in the coefficients which have been computed for the formula.

The coefficients derived from any pair of stations differ, by small amounts, from those derived from another pair of suitably situated stations, for the same short interval. The coefficients are identical in this case, and the deviations are clearly due to the results of observation.

The coefficients derived each year, from all the stations, differ from each other by such small amounts as could arise from errors of ob-

servation, when some allowance is made for systematic as well as accidental errors.

The representation of observed results by graphical methods has much to recommend it, as long as the graphical lines are not too much adjusted, or "smoothed," to fit. When the periodic curve is a regular curve, such as that given by a sine cosine formula, it may fail to pass through a single one of the plotted points, and still represent them all better than a partially smoothed curve.

Summing up some conclusions, with respect to changes of position on the surface of the earth, if our meridian circle results have probable errors of the order of 0".1 for quarterly values, it appears to be useless to look to these for the confirmation of geologic changes of from one to five feet. Even the probable error of annual values appears to be too large for the purpose.

The zenith telescope results have probable errors, in general, of one third this size. Differences of 0".05 would be expected in half the cases of comparison of latitudes at tenths of a year. Differences of 0".03 would be expected in half the cases of comparison of yearly values, at any station.

It must be recalled, in this connection, that the apparent thickness of the micrometer thread in our meridian instrument is closely one second of arc. Single hundredths of a second must be reckoned on this scale. They are significant in mean values, however.

In regard to the errors of standard star declinations, the following comparison of authorities for three of the best determined stars may be instructive. The best observed star in the sky is undoubtedly *Polaris*. From its situation so near the pole, the errors of refraction are nearly eliminated in the mean declination from both culminations. Flexure and the systematic bisection errors are also eliminated. Graduation errors are not eliminated, but will be represented by a constant for the same instrument in the same position.

These errors that eliminate in measures of the declination, from the two culminations, act as constant errors for both culminations in the corresponding measures of latitude—that is they are not eliminated.

The star β *Urs. Min.* is not so favorably situated, since there is a difference of more than thirty degrees between the zenith distances of the two culminations, and we cannot expect so close an elimination of errors due to refraction.

The star α *Andromedae* passes so near the zenith of many of our northern observatories that errors of refraction should be small. But the actual determination of its declination, by fundamental observations, is of course affected by the error in the observed zenith distance of the pole.

The three stars happen to be chosen for illustration here because they were under frequent observation in all our fundamental work, since they can all be easily seen at any hour of the day that they transit

our meridian. The declinations for 1900 of five authorities are quoted here, with the range of the extreme values. Also the range is given for the three most modern catalogues, the second, fourth and fifth of the list.

	α *Androm.* 28°.5	*Polaris* 88°.8	β *Urs. Min.* 74°.6
Auwers, Old System,	18″.20	26″.63	50″.70
Auwers, New System,	17.96	26.51	51.15
Boss, N. B. S.	17.78	26.54	50.95
Boss, P. G. C.	17.86	26.49	51.10
Newcomb,	18.01	26.61	51.05
Range (5)	0.42	0.14	0.45
Range (3)	0.15	0.12	0.10

One would appear to be justified in allowing errors of a tenth of a second for the declinations of these stars, especially since there is likely to be a systematic error that is common to all the authorities. With many hundred observations, at all epochs since precise meridian work began, these are the best results we have. The purely accidental errors of observation account for only a small part of this final error. Systematic errors, due to each instrument, and possibly to each observer, must be accepted as accounting for the balance. These may be partially eliminated, in the mean of many instruments, but can not be entirely disposed of, evidently, in any combination.

Apparent changes in the latitude, at fixed observatories, may be due to the lack of precision in the adopted proper motions of standard stars, and also in part to changes in the systematic habits of individual observers. The stars of the zenith telescope lists are of less precision, both as regards declinations and proper motions.

These points may be illustrated by the comparison of the declinations and proper motions of eight standard stars employed here in the observations of the *Com. Ber.* Cluster, in 1921. The fundamental stars were selected so as to give the mean position of the cluster, and with the condition that they would be contained in the standard catalogues, Auwers, Newcomb, and Boss P. G. C.

Boss — Newcomb	$\Delta\delta$ — 0″.53	Δ P. M. — 0″.005
Boss — Auwers	— 0.37	— 0.005

There would be a difference of 0″.53 in the latitudes derived from the declinations of Boss and Newcomb, at this epoch. And if the system of Boss was adopted for continued observation of these stars, the resulting latitudes would have an annual change that differs by 0″.005 from that given by the system of Newcomb.

The full comparison of all the stars common to two of the authorities, in this region of the sky gives the following systematic differences.

Boss — Newcomb	$\Delta\delta$ — 0″.28	Δ P. M. 0″.000
Boss — Auwers	— 0.22	— 0.002

Without a comparison of the individual stars of this short list, the adopted systematic correction for Newcomb would have been 0″.25 in error, and that of Auwers 0″.15 in error. These errors are evidently

due to the proper motions of the individual stars, which differ from the means of two authorities.

This gives us an illuminating illustration of the weakness of many systematic corrections. The only rigorous correction, to reduce one system to another, must be based upon the stars common to both. When we have extra stars in one system only, we may apply the mean correction as the best expedient we have; but if the original comparison is weak, numerically, the corrected result may not be as good as if the systematic difference had been left out, that is treated as zero.

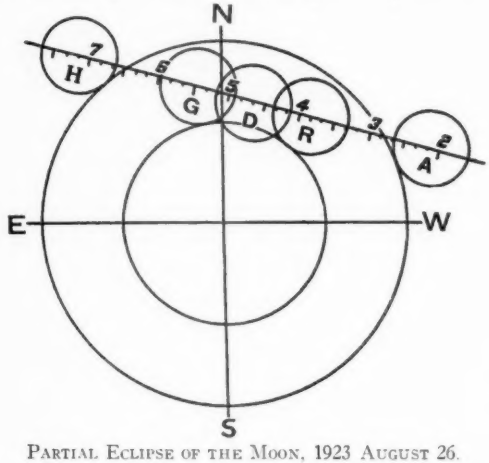
Many treatments of catalogues of faint stars have had this elemental weakness. Systematic corrections have often done more harm than good, and might well have been omitted, in the absence of suitably numerous comparisons as foundation.

October 3, 1922.

PARTIAL ECLIPSE OF THE MOON, 1923 AUGUST 26.

WILLIAM F. RIGGE.

In its partial eclipse of next August 26 the moon dips into the northern part of the earth's shadow, while it was in the southern part last March 2. The large circle on the diagram represents a cross sec-



PARTIAL ECLIPSE OF THE MOON, 1923 AUGUST 26.

	Central Time
A—Moon enters Penumbra	2:12 A. M.
B—Moon enters Shadow	3:52
D—Middle of Eclipse	4:40
G—Moon leaves Shadow	5:27
H—Moon leaves Penumbra	7:06

tion of the earth's penumbra, and the next one the umbra or shadow. The oblique line is moon's path, and the five small circles give its position at important moments. When its center is at A, at 2:12 A. M. Central Time, the moon enters penumbra. At B, at 3:52, the moon enters shadow. At D, at 4:40, there is the Middle of the Eclipse when the moon has advanced deepest into the earth's shadow, with 17 per cent of its diameter obscured. At G, at 5:27, the moon leaves shadow, and at H, at 7:06, the moon leaves penumbra.

ECLIPSE OF THE SUN, 1923 SEPTEMBER 10, AS VISIBLE IN THE UNITED STATES.

WILLIAM F. RIGGE.

The coming eclipse of the sun, 1923, September 10, follows the last one visible in the United States after an interval of nearly three years (1920 November 10). It will be completely visible in all the states as a partial eclipse, with a magnitude ranging from less than 40 per cent to totality, although the totality belt will just skirt a part of the shore of California, so that only San Diego, Point Concepcion and the Santa Barbara Islands will be privileged to see the sun totally eclipsed. The accompanying three maps will probably give us all the circumstances that we may wish to know in advance for our locality.

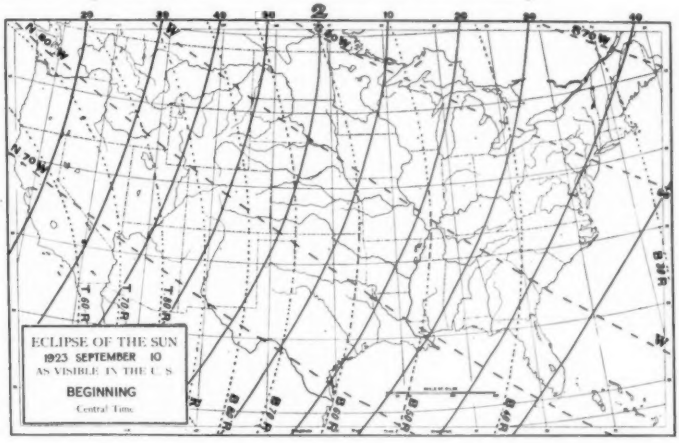


Fig. 1.

Fig. 1 is drawn for the beginning of the eclipse. The full lines show the Central Time for every ten minutes, from which by proportion we may interpolate it to single minutes, the large 2 on the upper margin meaning 2 o'clock, and the 10, 20, 30, 40, 50, the preceding and follow-

ing minutes. The dashed lines, S 70 W, S 80 W, W, N 80 W, N 70 W, show the position angles on the sun, counted from its north or south point towards the west, at which the moon will first indent it. The dotted lines marked B 30 R .... T 60 R, give the same point of First Contact measured from the lowermost or bottom point, B, of the disk, or from its vertex or top, T, towards the right, R.

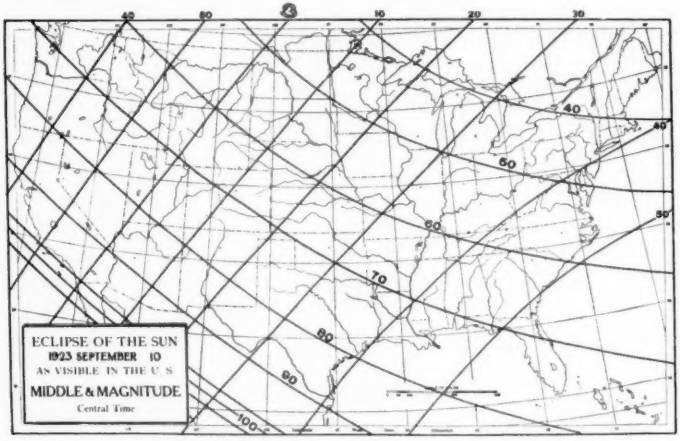


Fig. 2.

Fig. 2 gives the Central Times on the upper and right margin for the middle of the eclipse, when the obscuration is a maximum and reaches the percent indicated by the numbers from 40 to 100 on the

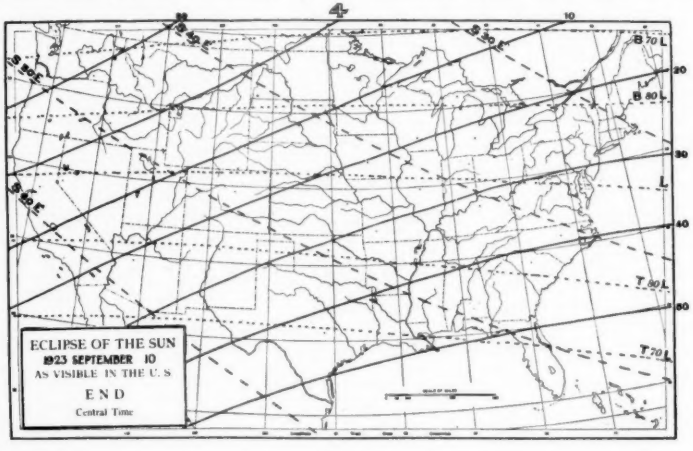


Fig. 3.

other set of lines. Fig. 4 shows the appearance of the sun corresponding to these different percentages of obscuration.

Fig. 3 pertains to the end of the eclipse, and gives in the full lines the Central Times when the moon will finally leave the sun, in the dashed lines, S 30 E .... S 60 E, the location of the point of Last Contact on the sun's disk counted from its south point towards the east, and in the dotted lines B 70 L .... L .... T 70 L, this position measured from the bottom, B, and top, T, towards the left.

All the lines on these three maps were located by a purely graphic process. A comparison of the results it furnishes with the numerical ones of the American Ephemeris pp. 562 and 563 for ten places, nine of which were close to the border of the map, shows that the mean

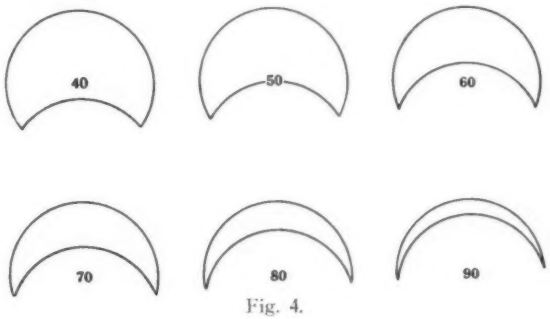


Fig. 4.

error of the times is $1^m.3$ (max. 3^m), of the position angles from the north point 0°.1 for the beginning and 1°.1 for the end (max. 3°), and from the vertex 1°.7 and 1°.4 (max. 5°), and of the magnitudes 2 per cent (max. 3°).

THE PLEIADES.

Enmeshed amidst a misty nebula,
The Pleiades, resplendent, rise again,
And shine like suns of night, or jewels wee,
On farm and fold, on field and fell and fen.

Alcyone shines there, and Merope,
Electra, Maia and Taygeta,
Celaeno and the twinned Asterope,
Each reigning like a queen, on high, afar.

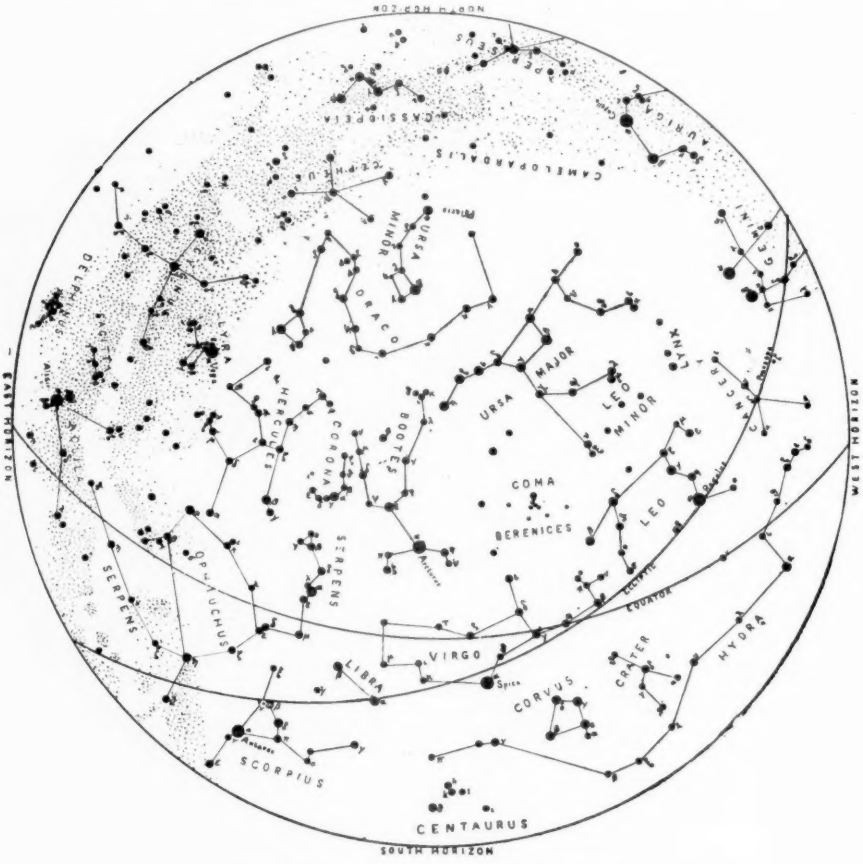
Earth's pristine people watched these Pleiads bright,
And centuries and centuries passed by;
Those stars that Job beheld, we see tonight,
The Seven Sisters shining in the sky.

CHARLES NEVERS HOLMES.

41 Arlington St., Newton, Mass.

PLANET NOTES FOR JUNE.

The ***sun*** will move northward until June 22, the date of the summer solstice. This also marks the beginning of summer, according to calendar reckoning. After this date the sun moves southward slowly, reaching declination +23° 13′ by June 30. It will move eastward from Taurus into Gemini and will render the Pleiades, Aldebaran, and Betelgeux invisible because of its nearness to them.



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1.

The phases of the *moon* will occur as follows:

Last Quarter	June 6 at 3 A. M.	C. S. T.
New Moon	14 " 7 A. M.	"
First Quarter	21 " 3 P. M.	"
Full Moon	28 " 7 A. M.	"

The *moon* will be farthest from the earth for the month on June 9, and nearest on June 25.

Mercury, having passed the sun on May 28, will continue to move westward until June 23, when it will be at a point of greatest elongation west. On this date it will rise about an hour and a half before the sun, at a point on the horizon a few degrees south of the sun.

Venus will continue to follow the sun eastward, gaining slightly on the sun during the month. It will be a few degrees south of the sun and not favorably situated for study. It will however be visible near the eastern horizon at sunrise.

Mars at the middle of the month will be only a little more than an hour ahead of the sun in their motion eastward. It will therefore be invisible during this month.

Jupiter will be in a favorable position in the evening during this month. At the middle of the month it will cross the meridian about nine o'clock. It will, however, still be thirteen degrees south of the equator.

Saturn will be very near the meridian at sunset during this month. It will be three degrees south of the equator.

Uranus will be in a position to be observed in the early morning during the month. It will be in the constellation Aquarius in a region in which there are no bright stars.

Neptune will be visible in the western sky after sunset early in the month. By the end of the month the sun will have moved very near it in the sky.

Phenomena of Jupiter's Satellites.

VISIBLE AT WASHINGTON.

[From the *American Ephemeris*.]

CENTRAL STANDARD TIME. NOON = 0^h

1923		h	m			1923		h	m		
June	1	7	36	I	Ec. R.	June	17	6	14	II	Sh. E.
	5	13	9	I	Tr. I.			8	7	III	Tr. I.
	6	10	21	I	Oc. D.			9	43	III	Tr. E.
		11	39	II	Tr. I.			11	46	III	Sh. I.
		13	4	II	Sh. I.		21	11	12	I	Tr. I.
		13	13	I	Ec. R.			12	10	I	Sh. I.
	7	7	36	I	Tr. I.		22	8	22	I	Oc. D.
		8	20	I	Sh. I.			11	5	II	Oc. D.
		9	45	I	Tr. E.			11	31	I	Ec. R.
		10	30	I	Sh. E.		23	7	48	I	Tr. E.
	8	7	42	I	Ec. R.			8	48	I	Sh. E.
		10	14	II	Ec. R.		24	7	31	II	Sh. I.
	10	7	47	III	Sh. I.			7	49	II	Tr. E.
		9	32	III	Sh. E.			9	49	II	Sh. E.
	13	12	8	I	Oc. D.			11	38	III	Tr. I.
	14	9	23	I	Tr. I.		28	7	34	III	Ec. R.
		10	15	I	Sh. I.		29	10	11	I	Oc. D.
		11	32	I	Tr. E.		30	7	29	I	Tr. I.
		12	25	I	Sh. E.			8	34	I	Sh. I.
	15	8	41	II	Oc. D.			9	38		Tr. E.
		9	36	I	Ec. R.			10	43	I	Sh. E.
		12	51	II	Ec. R.						

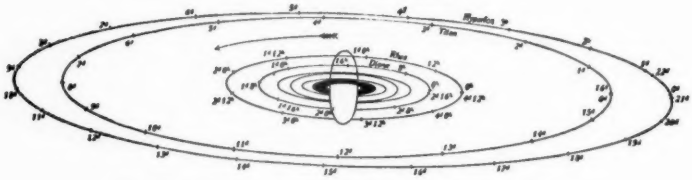
NOTE:—I. denotes ingress; E., egress; D., disappearance; R., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Occultations Visible at Washington.

[*From the American Ephemeris.*]

Date 1923	Star's Name	Magnitude	IMMERSION. Washington M.T.	Angle from N	EMERSION. Washington M.T.	Angle from N	Duration
			h m	°	h m	°	h m
June 1	267 B. Sagittarii	5.8	12 45	78	14 7	271	1 22
5	82 Aquarii	6.4	11 54	51	12 50	278	0 56
9	64 Ceti	5.8	15 23	80	16 27	238	1 4
22	θ Virginis	4.4	9 45	152	10 40	253	0 55
23	623 B. Virginis	6.5	8 40	44	9 8	2	0 28
23	κ Virginis	4.3	13 17	120	14 12	267	0 54
25	49 Librae	5.4	7 57	140	9 2	256	1 5
26	90 B. Ophiuchi	6.5	7 1	80	8 4	308	1 3
28	173 B. Sagittarii	6.4	8 6	114	9 8	252	1 2
28	171 B. Sagittarii	6.1	8 22	157	8 51	209	0 29

Saturn's Satellites.



Greatest elongations visible in the United States.

[From the *American Ephemeris.*]

CENTRAL STANDARD TIME. NOON = 0^h

I. Mimas. Period $0^d\ 22^h.6$.

1923	d	h		d	h		d	h		d	h
June	1	15.6 E	June	6	8.7 E	June	13	10.4 W	June	22	9.3 E
	2	14.2 E		7	7.3 E		14	9.0 W		23	7.9 E
	3	12.9 E		10	14.5 W		15	7.6 W		27	13.7 W
	4	11.5 E		11	13.1 W		19	13.4 E		28	12.3 W
	5	10.1 E		12	11.8 W		20	12.0 E		29	10.9 W
							21	10.6 E		30	9.5 W

II. Enceladus. Period $1^d\ 8^h.9$.

June	2	1.4 E	June	8	21.8 E	June	15	18.3 E	June	22	14.7 E
	3	10.3 E		10	6.7 E		17	3.2 E		23	23.6 E
	4	19.2 E		11	15.6 E		18	12.1 E		25	8.5 E
	6	4.1 E		13	0.5 E		19	20.9 E		26	17.4 E
	7	13.0 E		14	9.4 E		21	5.8 E		28	2.3 E
										29	11.2 E

III. Tethys. Period $1^d\ 21^h.3$.

June	2	1.4 E	June	9	14.6 E	June	17	3.3 E	June	24	17.1 E
	3	22.7 E		11	12.0 E		19	1.2 E		26	14.5 E
	5	20.0 E		13	9.3 E		20	22.5 E		28	11.8 E
	7	17.3 E		15	6.6 E		22	19.8 E		30	9.1 E

IV. Dione. Period $2^d\ 17^h.7$.

June	2	8.4 E	June	10	13.5 E	June	18	18.5 E	June	26	23.6 E
	5	2.1 E		13	7.1 E		21	12.2 E		29	17.3 E
	7	19.8 E		16	0.8 E		24	5.9 E			

V. Rhea. Period $4^d\ 12^h.5$.

June	2	16.8 E	June	11	17.6 E	June	20	18.4 E	June	29	19.3 E
	7	5.2 E		16	6.0 E		25	6.9 E			

VI. Titan. Period 15d 23h.3.

June 3 22.8 W June 11 23.5 E June 19 21.4 W June 27 22.3 E

VII. Hyperion. Period 21d 7h.6.

June 9 7.1 E June 18 13.9 W June 30 15.4 E

NOTE.—E, Eastern Elongation; W, Western Elongation.

COMET AND ASTEROID NOTES.

Elements of Baade's Comet *c* 1922.—The following elements of Baade's Comet *c* 1922 were computed by Mr. F. E. Seagrave from observations made with the 12½-inch telescope of the Detroit Observatory, Ann Arbor, Michigan:

ELEMENTS OF COMET *c* 1922 (BAADE).

T = Oct. 25.7463, 1922, G. M. T.
ω = 118° 10′ 54″.09
π = 338 40 43.72
Ω = 220 29 49.63
i = 51 27 59.57
log q = 0.3537646

CONSTANTS.

$x = r\,[9.9351840]\,\sin\,(298^\circ\ 00'\ 48''.94 + u)$
$y = r\,[9.9798264]\,\sin\,(218\ 37\ 02.59 + u)$
$z = r\,[9.7700265]\,\sin\,(333\ 58\ 22.83 + u)$

The Fifth Comet of 1922.—We are glad to correct a mistake, inadvertently made in our comet notes of last month, concerning the discovery of Perrine's periodic comet. Mr. Issei Yamamoto, now at the Yerkes Observatory, writes that "the fifth comet of last year was discovered, not by Professor Hirayama of Tokyo, but by Mr. K. Nakamura of Kyoto University Observatory, with which I have been connected since 1909. Mr. Nakamura wrote to me several times about the matter after his discovery, and the data of his observations of the comet are now in my hand. I am trying to get a reasonable set of elements from them..... .....He had a copy of the 'Handbook' of the British Astronomical Association which contained a search ephemeris of Perrine's comet. Following this he tried searching for the comet for a number of nights. At last, in the early morning of November 30 (Japanese C. S. T., Greenwich time being November 29) he found a faint object at R. A. 8h 05m and Decl. near equator. The diameter was estimated as 2′, but the object was so faint, that the estimated magnitude 13½ meant simply that it was at the limit of visibility with the 10-inch reflector. On the following two mornings he saw the same object and confirmed its motion, just parallel to the prediction. Further observations were prevented.

"Mr. Nakamura soon afterwards went to Tokyo and visited the observatory there, which accounts for the telegraphic announcement being sent to Copenhagen by Professor Hirayama.

"Mr. Nakamura had no micrometer nor photographic arrangement connected with his instrument, so that he had to make sketches of the observed fields at all times. These sketches are pretty accurate, but accuracy within one minute of arc seems to me not to be attained. However, he made three observations, from which a set of orbital elements may be obtained."

Ephemeris of Encke's Comet Near Aphelion.—Mr. F. E. Seagrave sends in the following ephemeris of Encke's comet when near its aphelion this summer. This was calculated at the request of the late Professor E. E. Barnard, who has, once or twice at least, attempted to photograph the comet when out farthest from the sun.

The next perihelion passage of Encke's comet will be on October 31, 1924.

EPHEMERIS OF ENCKE'S COMET.

Gr. Midnight 1923		α	δ	Log r	Log Δ
		h m s	° ′ ″		
June	1	23 46 12	+0 28 23	0.60660	0.62454
"	5	23 47 43	+0 42 31	0.60606	0.61758
"	9	23 49 2	+0 55 41	0.60548	0.61037
"	13	23 50 11	+1 7 50	0.60484	0.60291
"	17	23 51 7	+1 18 51	0.60422	0.59529
"	21	23 51 51	+1 28 40	0.60352	0.58744
"	25	23 52 21	+1 37 18	0.60284	0.57948
"	29	23 52 38	+1 44 25	0.60210	0.57135
July	3	23 52 39	+1 50 14	0.60134	0.56313
"	7	23 52 26	+1 54 33	0.60054	0.55481
"	11	23 51 56	+1 57 21	0.59972	0.54645
"	15	23 51 10	+1 58 27	0.59888	0.53809
"	19	23 50 6	+1 57 52	0.59802	0.52978
"	23	23 48 45	+1 55 30	0.59712	0.52157
"	27	23 47 7	+1 51 18	0.59620	0.51353
"	31	23 45 11	+1 45 19	0.59522	0.50562
August	4	23 42 57	+1 37 25	0.59424	0.49804
"	8	23 40 26	+1 27 37	0.59322	0.49074
"	12	23 37 37	+1 15 59	0.59216	0.48384
"	16	23 34 33	+1 2 32	0.59106	0.47738
"	20	23 31 14	+0 47 18	0.58994	0.47150
"	24	23 27 41	+0 30 28	0.58880	0.46620

Ephemeris of Comet *d* 1922 (Skjellerup).

Gr. Midnight 1923		α	δ	Log r	Log Δ
		h m s	° ′ ″		
July	1	18 14 42	−14 23 45	0.45544	0.26676
"	9	18 6 14	−13 56 49	0.46954	0.29310
"	17	17 59 20	−13 36 38	0.48308	0.32154
"	25	17 54 5	−13 22 44	0.49614	0.35141
August	2	17 50 28	−13 14 4	0.50868	0.38179
"	10	17 48 25	−13 9 55	0.52078	0.41225
"	18	17 47 44	−13 9 20	0.53234	0.44219
"	26	17 48 27	−13 10 44	0.54374	0.47159
Sept.	3	17 50 15	−13 13 58	0.55464	0.49986
"	11	17 53 3	−13 18 1	0.56518	0.52694
"	19	17 56 44	−13 22 11	0.57540	0.55278

The above is an ephemeris of Comet *d* 1922 (Skjellerup) for two and a half months of the summer of 1923. The ephemeris is based upon parabolic elements by Professor Chacon published in a recent number of the Astronomical Journal.

FRANK E. SEAGRAVE.

Boston, April 18, 1923.

VARIABLE STARS.

New Variable with Remarkable Spectrum and Light Curve.—The tenth magnitude star H. D. 81137, for which the position is $9^h\ 18^m7$, $-52°\ 8'$ (1900), has been found to be variable from an examination of its spectrum by Miss Cannon. The spectrum and the light variation are both of unprecedented types.

The spectrum, which is of Class Ma, contains also five well-marked bright lines or bands, which appear, on the dispersion available, to coincide with some of the strongest bright lines of unknown origin in the spectrum of η Carinae. The approximate positions are 4244 (perhaps including the enhanced iron line 4233), 4287, 4352 to 4358, 4414 to 4416, and 4452 to 4457. The last is much fainter than the other four. Hβ does not appear as a bright line.

The magnitude of the star has been measured by two observers on 101 photographs that are distributed rather evenly throughout the years from 1890 to 1922. From 1890 to 1901 there was a slow and apparently steady increase in light from magnitudes 9.8 to 9.2; and since 1902 the light has slowly decreased. The magnitude was 10.1 in May, 1922.

The spectrum was studied on plates made on April 9, 1902, with the 24-inch Bruce telescope and on May 15, 1922, with the 10-inch Metcalf telescope.

Harvard College Observatory Bulletin 783.
Cambridge, Massachusetts, March 19, 1923.

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1923							
									June			
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7	9 8							
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	7 10		11 12		15 13		23 17	
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	7 2		14 19		22 13		30 7	
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	3 12				18 8			
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 21		13 20		21 18		29 17	
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	5 4		13 0		20 19		28 14	
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0			10 17		27 2			
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	6 0		14 14		23 4		27 11	
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	2 3		13 6		24 10			
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0			11 6		22 21			
SX Aurigæ	5 04.6	+42 02	8.0— 8.7	1 12.8	3 22		11 14		19 6		26 21	
SY Aurigæ	05.5	+42 41	8.4— 9.5	10 03.3	10 4		20 7		30 11			
Y Aurigæ	21.5	+42 21	8.6— 9.6	3 20.6	8 11		16 4		23 21		27 17	
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	6 8		11 21		22 22		28 11	
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	7 18		15 8		22 22		30 11	
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3					27 8			
RT Aurigæ	23.0	+30 33	5.1— 6.0	3 17.5	7 6		14 17		22 3		29 15	
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	2 0		9 22		17 20		25 18	
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	3 6		13 10		23 14			
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5			17 9					
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	6 4		14 3		22 2		30 0	
V Carinæ	8 26.7	—59 47	7.4— 8.1	6 16.7	5 10		12 3		18 20		25 12	
T Velorum	8 34.4	—47 01	7.6— 8.5	4 15.3	6 11		15 18		25 1			

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900		Decl. 1900		Magnitude	Approx. Period		Greenwich mean times of maxima in 1923 June							
	h	m	°	′		d	h	d	h	d	h	d	h	d	h
V Velorum	9	19.2	−55	32	7.5— 8.2	4	08.9	8	21	17	14	21	23	26	8
Z Leonis	9	46.4	+27	22	7.9— 9.6	59	00.0			12	7				
RR Leonis	10	02.1	+24	29	9.1—10.1	0	10.9	6	4	13	23	20	18	27	13
SU Draconis	11	32.2	+67	53	8.9— 9.6	0	15.8	7	10	14	0	20	15	27	6
S Muscae	12	07.4	−69	36	6.4— 7.3	9	15.8	4	15	14	7	23	22		
SW Draconis		12.8	+70	04	8.8— 9.6	0	13.7	2	13	10	13	18	12	26	12
T Crucis		15.9	−61	44	6.8— 7.6	6	17.6	7	5	13	23	20	16	27	10
R Crucis		18.1	−61	04	6.8— 7.9	5	19.8	1	11	7	6	18	22	24	18
S Crucis	12	48.4	−57	53	6.5— 7.6	4	16.6	5	14	14	23	19	16	29	1
W Virginis	13	20.9	− 2	52	8.7—10.4	17	06.5			18	1				
SS Hydræ		25.0	−23	08	7.4— 8.1	8	04.8	7	0	15	5	23	10		
RV Urs. Maj.	13	29.4	+54	31	9.2— 9.9	0	11.2	5	10	12	11	19	11	26	12
ST Virginis	14	22.5	− 0	27	10.3—11.4	0	09.9	5	11	13	16	21	22	30	3
V Centauri		25.4	−56	27	6.4— 7.8	5	11.9	3	2	8	14	19	14	25	2
RS Bootis		29.3	+32	11	8.9—10.0	0	09.1	8	10	15	23	23	12	27	7
R Triang.Austr.	15	10.8	−66	08	6.7— 7.4	3	09.3	5	5	12	1	18	19	25	13
S Triang.Austr.	15	52.2	−63	29	6.4— 7.4	6	07.8	1	6	7	13	20	5	26	13
S Normæ	16	10.6	−57	39	6.6— 7.6	9	18.1	1	16	11	9	21	3	30	22
RW Draconis		33.7	+58	03	9.6—10.8	0	10.6	1	23	10	20	19	16	28	13
RV Scorpii	16	51.8	−33	27	6.7— 7.4	6	01.5	2	18	8	19	20	22	27	0
X Sagittarii	17	41.3	−27	48	4.4— 5.0	7	00.3	3	9	10	9	17	9	24	10
Y Ophiuchi		47.3	− 6	07	6.1— 6.5	17	02.9	1	3			18	6		
W Sagittarii	17	58.6	−29	35	4.3— 5.1	7	14.3	4	3	11	7	19	8	26	21
Y Sagittarii	18	15.5	−18	54	5.4— 6.2	5	18.6	4	4	9	22	21	12	27	6
U Sagittarii		26.0	−19	12	6.5— 7.3	6	17.9	4	5	10	23	17	17	24	11
Y Scuti		32.6	− 8	27	8.7— 9.2	10	08.3	9	21	20	5	30	13		
RZ Lyræ	18	39.9	+32	42	9.9—11.2	0	12.3	2	5	8	8	20	15	26	18
RT Scuti	18	44.1	−10	30	9.1— 9.7	0	11.9	4	16	10	14	22	12	28	11
κ Pavonis	18	46.6	−67	22	3.8— 5.2	9	02.2	4	14	13	16	22	19		
U Aquilæ	19	24.0	− 7	15	6.2— 6.9	7	00.6	7	21	14	22	21	23	28	23
XZ Cygni	19	30.4	+56	10	8.6— 9.3	0	11.2	3	21	10	21	17	21	24	21
U Vulpec.		32.2	+20	07	6.5— 7.6	7	23.5	5	19	13	18	21	18	29	17
SU Cygni		40.8	+29	01	6.2— 7.0	3	20.3	7	10	15	3	22	20	30	12
η Aquilæ		47.4	+ 0	45	3.7— 4.5	7	04.2	4	5	11	10	18	14	25	18
S Sagittæ		51.5	+16	22	5.6— 6.4	8	09.2	4	16	13	1	21	10	29	14
X Vulpec.	19	53.3	+26	17	9.5—10.5	6	07.7	4	13	9	20	22	12	28	19
X Cygni	20	39.5	+35	14	6.0— 7.0	16	09.3	6	11			22	23		
T Vulpec.		47.2	+27	52	5.5— 6.1	4	10.5	1	14	10	11	19	8	28	5
WY Cygni		52.3	+30	03	9.6—10.4	0	13.5	6	15	13	8	20	2	26	19
RV Capric.		55.9	−15	37	9.2—10.1	0	10.7	6	23	13	16	20	9	27	2
TX Cygni	20	56.4	+42	12	8.5— 9.7	14	17.4			14	21	29	14		
VY Cygni	21	00.4	+39	34	8.8— 9.5	7	20.6	6	21	14	18	22	15	30	11
SW Aquarii		10.2	− 0	20	9.9—10.8	0	11.0	3	7	10	4	17	2	23	23
VZ Cygni	21	47.7	+42	40	8.2— 9.2	4	20.7	3	16	13	9	18	6	28	0
Y Lacertæ	22	05.2	+50	33	9.1— 9.6	4	07.8	5	4	13	19	22	11	26	19
δ Cephei		25.5	+57	54	3.7— 4.6	5	08.8	1	2	11	20	22	13	27	22
Z Lacertæ		36.9	+56	18	8.2— 9.0	10	21.1	1	13	12	11	23	8		
RR Lacertæ		37.5	+55	55	8.5— 9.2	6	10.1	5	11	11	21	18	7	24	17
V Lacertæ		44.5	+55	48	8.5— 9.5	4	23.6	2	16	12	16	17	15	27	14
X Lacertæ	22	45.0	+55	54	8.2— 8.6	5	10.7	1	13	12	10	17	21	28	18
SW Cassiop.	23	03.7	+58	11	9.2— 9.7	5	10.6	4	14	10	1	20	22	26	9
RS Cassiop.		32.6	+61	52	9.0—11.0	6	07.1	1	19	8	2	20	16	26	23
RY Cassiop.		47.2	+58	11	9.3—11.8	12	03.4	9	3			21	6		
V Cephei	23	51.7	+82	38	6.0— 7.0	0	23.9	6	0	12	23	19	23	26	23

Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1923 June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8					20 6			
RT Sculptor.	31.5	—26 13	9.6—10.5	0 12.3	2 23		10 15		18 7		25 23	
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	7 1		14 13		22 1		29 12	
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	6 10		12 12		24 18		30 21	
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	2 1		10 14		19 4		27 17	
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	4 2		10 22		17 19		24 16	
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	4 12		11 16		18 20		26 1	
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	6 18		15 13		24 8		27 6	
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	1 12		9 10		17 9		25 8	
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6			15 10					
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	9 8		17 22		26 13		29 10	
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	5 13		12 8		19 3		25 22	
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	7 5		15 3		23 1		30 22	
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	1 10		9 17		18 1		26 8	
RV Persei	4 04.2	+33 59	9.5—12.0	1 23.4	8 1		15 23		23 20		27 19	
RW Persei	13.3	+42 04	8.8—11.0	13 04.8			10 20		24 0			
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	1 16		11 3		20 13		30 0	
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	3 6		15 16		28 2			
TT Aurigæ	5 02.8	+39 27	7.8— 8.7	0 16.0	2 3		8 20		22 3		28 20	
RY Aurigæ	11.5	+38 13	10.7—11.7	2 17.5	6 23		15 3		23 7		26 1	
RZ Aurigæ	42.9	+31 40	10.6—13.3	3 00.3	5 21		11 21		23 22		29 23	
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	9 12		18 4		26 20		29 0	
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	6 13		16 23		22 4		27 9	
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	2 21		10 21		18 21		26 22	
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	4 5		9 23		21 9		27 3	
U Columbæ	6 11.2	—33 03	9.2—10.0	2 19.2	4 0		9 15		20 2		26 10	
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	1 4		9 9		17 13		25 18	
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	3 8		10 23		18 14		26 5	
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	2 19		15 0		27 5			
RU Monoc.	6 49.4	— 7 28	9.8—10.5	0 21.5	2 2		9 5		23 13		30 18	
R Can. Maj.	7 14.9	—16 12	5.8— 6.4	1 03.3	4 13		11 8		18 4		24 23	
RY Gemin.	21.7	+15 52	8.9—<10	9 07 2	6 1		15 10		24 15			
Y Camelop.	27.6	+76 17	9 5—12	3 07.3	1 2		7 17		20 22		27 12	
TX Gemin.	30.3	+17 08	10.0—11.9	2 19.2	4 7		7 2		16 12		23 22	
RR Puppis	43.5	—41 08	9.4—10.7	6 10.3	2 13		8 23		21 20		28 6	
V Puppis	7 55.4	—48 58	4.1— 4.8	1 10.9	2 13		9 19		17 2		24 8	
X Carinae	8 29 1	—58 53	7.9— 8.7	0 13.0	8 8		16 11		24 14		30 0	
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	2 22		12 10		21 22			
RX Hydræ	9 00.8	— 7 52	9.1—10.5	2 6.8	6 11		13 7		20 4		27 0	
S Velorum	29.4	—44 46	7.8— 9.3	5 22.4	6 9		12 7		18 6		24 4	
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	7 2		13 20		20 14		27 7	
RR Velorum	10 17.8	—41 36	10.0—10.9	1 20.5	5 16		13 2		20 12		27 23	
SS Carinæ	10 54.2	—61 23	12.2—12 8	3 07.2	3 7		9 21		23 2		29 17	
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	8 9		17 4		26 0			
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	3 23		11 7		18 15		25 23	
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	2 23		9 18		23 8		30 3	
RZ Centauri	12 55.6	—64 05	8.5— 8.9	1 21.0	7 1		14 14		22 1		29 14	
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	8 8		17 23		22 18		27 13	
SS Centauri	07.2	—63 37	8.8—10.4	2 11.5	5 5		12 16		20 2		27 13	
1339.26 Hydræ	13 39.0	—26 23	8.6—12.7	2 21.5	5 6		11 1		22 15		28 10	

Minima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1923							
					June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h
δ Libræ	14 55.6	— 8 07	4.8— 6.2	2 07.9	7 11	14 10	21 10	28 10				
U Coronæ	15 14.1	+32 01	7.6— 8.7	3 10.9	5 11	12 8	19 6	26 4				
TW Draconis	15 32.4	+64 14	7.3— 8.9	2 19.3	2 16	11 2	19 12	27 22				
SS Librae	15 43.4	—15 14	9.3—11.5	0 18.4	2 1	9 6	23 15	30 19				
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	7 20	15 4	22 12	29 20				
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	7 5	15 11	23 17	27 20				
R Aræ	31.1	—56 48	6.8— 7.9	4 10.2	3 14	12 10	21 7	30 3				
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1		19 23						
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	5 13	12 8	19 3	25 23				
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	1 1	9 10	17 19	26 4				
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	4 12	10 16	22 23	29 3				
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	4 3	10 8	22 16	28 21				
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	6 1	13 11	20 19	28 4				
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	5 15	13 19	22 0	30 4				
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	5 0	12 13	20 2	27 15				
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	5 16	13 10	21 4	28 22				
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	4 10	13 0	20 9	28 9				
WX Sagittarii	53.6	—17 24	9.2—10.8	2 03.1	4 11	12 23	21 11	30 0				
WY Sagittarii	17 54.9	—23 1	9.5—10.6	4 16.0	2 1	11 9	20 17	30 2				
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	7 18	18 2	23 6	28 10				
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	1 6	8 12	23 0	30 6				
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	3 20	10 18	17 16	24 14				
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	2 17		17 20					
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	6 14	13 18	20 22	28 2				
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	7 13	14 16	21 19	28 22				
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	1 17	11 0	18 8	26 15				
RR Draconis	40.8	+62 34	9.3—13	2 19.9	5 0	12 12	22 0	29 12				
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	6 0	11 16	18 7	24 23				
β Lyræ	46.4	+33 15	3.4— 4.1	12 21.8	9 12		22 10					
U Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	5 0	12 16	20 7	27 23				
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	8 12	16 2	23 16	27 11				
RV Lyræ	12.5	+32 15	11. —12.8	3 14.4	5 2	12 7	19 12	26 17				
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	4 10	13 9	22 8	26 19				
U Sagittæ	14.4	+19 26	6.5— 9.0	3 09.1	6 5	13 0	19 18	26 12				
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	7 2	14 11	21 20	29 5				
TT Lyræ	24.3	+41 30	9.4—11.6	5 05.8	5 17	10 23	21 11	26 17				
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	1 15	8 4	21 5	27 17				
SY Cygni	19 42.7	+32 28	10. —12	6 00.2	3 22	9 22	21 23	27 23				
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	2 14	9 6	22 12	29 3				
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	9 15	18 18	23 8	27 22				
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	2 10	10 20	19 6	27 17				
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	7 10	14 5	21 0	27 18				
UW Cygni	19.6	+42 55	10.5—13	3 10.8	4 15	11 12	18 10	25 8				
V Vulpec.	32.3	+26 15	8.2— 9.8	37 19.0			20 12					
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	4 15	14 6	19 1	23 20				
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	7 16	16 21	21 11	26 2				
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	4 1	13 1	22 1	25 1				
WZ Cygni	48.3	+38 27	9.9—10.8	0 14.0	8 1	15 15	23 5	30 19				
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	5 2	15 4	20 5	25 7				
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	1 8	9 5	17 1	24 22				
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	2 20	13 1	15 2	23 3				
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3				30 7				
RW Lacertæ	22 40.6	+49 08	10.2—11.2	5 04.4	1 16	6 20	17 5	27 14				
VW Pegasi	51.7	+32 41	10.0—10.6	5 06.4	2 9	12 22	18 5	28 18				
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	7 15	15 4	22 17	30 5				
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	1 11	9 17	17 23	26 4				

Variable Star in Hercules.—On photographs made with the 16-inch Metcalf telescope, Miss Woods has found a new variable star for which the position for 1900 is

R. A. $16^h\ 51^m\ 4^s$. Dec. $+49°\ 6'.2$

The photographic magnitude varies from 12.0 to less than 13.0. The galactic coördinates are longitude 42°, latitude $+38°$.

Harvard College Observatory Bulletin 784.
Cambridge, Massachusetts, April 2, 1923.

Monthly Report of the American Association of Variable Star Observers, February 20 to March 20, 1923.

Secretary Olcott is sojourning in the south, and according to advices from that quarter he has proven a good fisherman as well as a good lecturer.

President Young is to spend the balance of the college term at the Yerkes Observatory, and possibly she may have a chance to observe some of the faint variables with the 40-inch.

Miss Margaret Harwood, our Nantucket member, sailed recently for Arequipa, Peru, where she expects to spend a few months studying the southern heavens. She plans to leave there in time to observe the eclipse of next September.

The slides continue to be used, lectures having been given recently by Messrs. Campbell, Olcott, Grimley, Poor, Markham, and Pickering.

Mr. McAteer reports that the library is being actively used, and requests that members enclose postage when ordering books.

Mr. Rhorer's experiment at Miami, Florida, where he had a 5-inch telescope available to the general public, proved to be a great success. More than a thousand visitors enjoyed the opportunity to view the stars and planets, and considerable interest was evinced by one and all. He plans to repeat the experiment another year and also to interest someone in undertaking variable star observing.

In spite of the unfavorable location of SS Cygni, Messrs. McAteer and Peltier succeeded in catching this variable at a maximum.

Mr. Brocchi reports good progress with the construction of his reflector and dome. Mr. Elmer is building a dome at Southold, Long Island, for his 6¼-inch refractor.

Attention is called to the approaching Spring Meeting of the Association, to be held at Southold, Long Island, on May 26, 1923. Mr. and Mrs. C. W. Elmer are to be the hosts, and a cordial invitation is extended to all members to attend. Those who intend to be present should advise Mr. Elmer at an early date.

Members are urged to send in their reports so as to reach the recording secretary and Harvard Observatory on the 20th of each month.

The following observers contributed to this report: Ancarani "An" 3, Aurino "Au" 6, Baldwin "Bl" 8, Bouton "B" 6, Brocchi "Br" 6, Chandler "Cd" 3, Chandra "Ch" 3, Christie "Ct" 2, Cunningham "Cu" 2, Eaton "E" 12, Jacobsen "Jb" 5, Miss Jenkins "Jk" 3, Kanda "Kd" 2, Lacchini "L" 5, Leavenworth "Lv" 10, McAteer "M" 5, 13, Marshall "Mh" 3, Merrill "Ml" 6, Peltier "Pt" 6, de Perrot "Pe" 4, Skaggs "Sg" 5, Watson "Pw" 6, Yalden "Ya" 4, and Miss Young "Y" 8.

Howard O. Eaton, Recording Secretary.

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923.

February 0 = J. D. 2423451 March 0 = J. D. 2423479

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
000339 V SCULPTORIS—						
	3396.0	[13.3	Bl.	3440.0	11.3	Bl.
	3429.0	12.9	Bl.	3449.0	10.8	Bl.
001032 S SCULPTORIS—						
	3429.0	7.5	Bl.	3448.9	8.5	Kd.
	3440.0	8.1	Bl.	3449.0	8.6	Bl.
001620 T CETI—						
	3447.9	5.8	Kd.	3454.9	5.8	Kd.
001755 T CASSIOPEIAE—						
	3351.0	10.3	Jk.	3479.3	10.7	L.
	3384.9	10.5	Jk.	3487.6	11.2	Pt.
001838 R ANDROMEDAE—						
	3426.1	11.4	Ch.	3459.9	9.0	Kd.
	3428.7	11.2	Ml.	3460.1	9.0	Ch.
	3434.1	11.3	Ch.	3464.1	8.9	Cd.
	3449.0	9.6	Kd.	3470.5	8.5	Cd.
	3450.1	9.6	Ch.	3477.6	8.2	Ct.
	3453.9	9.0	Kd.	3487.6	8.0	Pt.
	3455.1	9.1	Ch.	3488.5	8.9	Cd.
	3456.5	9.3	Cu.	3496.5	8.8	Cd.
001862 S TUCANAE—						
	3363.0	8.3	Bl.	3417.0	10.0	Bl.
	3374.0	8.8	Bl.	3429.0	10.4	Bl.
	3383.0	8.4	Bl.	3440.0	11.1	Bl.
	3393.0	8.7	Bl.	3449.0	11.4	Bl.
	3402.0	9.0	Bl.			
001900 S CETI—						
	3437.1	8 4	Ch.	3456.5	9.6	Cu.
	3447.0	9.0	Ch.	3460.1	9.8	Ch.
	3448.9	8.8	Kd.	3472.3	9.9	L.
002546 T PHOENICIS—						
	3429 0	13.5	Bl.			
002833 W SCULPTORIS—						
	3429.0	13.1	Bl.			
003179 Y CEPHEI—						
	3477 6	9.0	Br.			
004047 U CASSIOPEIAE—						
	3487.6	13.0	Y.	3487.6	13.1	Pt.
004435 V ANDROMEDAE—						
	3483.6	11.5	Lv.			
004435 X SCULPTORIS—						
	3429.0	11.5	Bl.	3440.0	11.9	Bl.
004746a RV CASSIOPEIAE—						
	3473.3	11.6	L.	3487.6	12.0	Pt.
	3482.5	10.5	B.			
004958 W CASSIOPEIAE—						
	3487.6	8.8	Pt.			
005475 U TUCANAE—						
	3429.0	14.5	Bl.			
010630 U SCULPTORIS—						
	3429.0	10 1	Bl.	3449.0	10.7	Bl.
	3440.0	10.7	Bl.			
011272 S CASSIOPEIAE—						
	3483.6	12.4	Lv.	3487.6	12.3	Pt.
011712 U PISCIUM—						
	3487.6	11.9	Pt.			
012233a R SCULPTORIS—						
	3454.9	6.8	Kd.			
012350 RZ PERSEI—						
	3487.5	10.0	Y.			
013238 RU ANDROMEDAE—						
	3487.6	13.5	Pt.			
013338 Y ANDROMEDAE—						
	3429.2	9.6	Ch.	3467.1	9.8	Ch.
	3441.2	9.7	Ch.	3487.6	11.5	Pt.
	3455.1	9.7	Ch.			
014958 X CASSIOPEIAE—						
	3487.6	11.0	Y.	3487.6	11.6	Pt.
015354 U PERSEI—						
	3485.7	8.9	Sg.	3487.6	8.8	Pt.
015912 S ARIETIS—						
	3487.6	13.0	Pt.			
021024 R ARIETIS—						
	3472.3	13.7	L.	3487.6	12.7	Pt.
021143a W ANDROMEDAE—						
	3487.6	12.4	Pt.			
021281 Z CEPHEI—						
	3471.6	11.7	B.	3477.7	11.5	Br.
021403 o CETI—						
	3437.2	6.8	Ch.	3465.1	3.4	Ch.
	3449.1	4.6	Ch.	3465.3	3.4	An.
	3450.9	4.3	Kd.	3466.2	3.2	An.
	3451.9	4.1	Kd.	3466.3	3.3	Pe.
	3452.9	4.0	Kd.	3467.7	3.4	Jb.
	3453.0	4.2	Ch.	3467.9	3.4	Kd.
	3453.9	4 0	Kd.	3468.5	3.4	Cu.
	3454.9	3.9	Kd.	3470.1	3.2	Ch.
	3455.9	4.0	Kd.	3470.7	3.0	Jb.
	3456.5	3.8	Cu.	3471.3	3.2	Pe.
	3457.3	3.9	An.	3472.3	2 9	L.
	3458.5	3.8	Cu.	3476.7	2.5	Sg.
	3459.0	3.9	Kd.	3472.3	3.0	An.
	3459.1	3.8	Ch.	3473.3	2.7	An.
	3459.9	3.7	Kd.	3478.1	2.9	Ch.
	3460.7	3.6	Jb.	3479.3	3.0	L.
	3460.9	3.7	Kd.	3487.6	2.5	Pt.
	3463.7	3.5	Jb.	3487.7	3.0	Sg.
	3464 3	3.5	An.	3490.7	3.0	Sg.
	3464.7	3.4	Jb.			
021558 S PERSEI—						
	3354.0	10.7	Jk.	3487.6	11.0	Pt.
	3485.6	10.4	B.			
022150 RR PERSEI—						
	3487.6	10.0	Y.	3487.6	10.0	Pt.
022426 R FORNACIS—						
	3429.0	10.6	Bl.	3449.0	10.8	Bl.
	3440.0	11.0	Bl.			
022813 U CETI—						
	3437.2	9.4	Ch.	3462.1	10.8	Ch.
	3448.9	9.8	Kd.			
023133 R TRIANGULI—						
	3449.0	10.6	Kd.	3482.5	11.3	B.
	3462.5	11.4	Cu.	3487.6	11.4	Pt.
	3471.6	11.4	B.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
024356 W PERSEI—						
	3464.7	10.0	Jb.	3485.6	9.1	B.
	3467.7	10.2	Jb.	3487.6	9.2	Pt.
	3470.7	10.0	Jb,	3496.5	9.5	Ya.
025050 R HORAE—						
	3429.0	12.4	Bl.			
025751 T HORAE—						
	3429.0	11.0	Bl.	3449.0	9.9	Bl.
	3440.0	10.4	Bl,			
030514 U ARIETIS—						
	3487.6	12.8	Y.	3493.6	12.4	Y.
031401 X CETI—						
	3448.9	9.6	Kd.	3487.6	9.3	Pt.
	3472.3	9.0	L,			
032043 Y PERSEI—						
	3487.6	7.9	Pt.	3497.5	8.6	Ya.
	3488.6	8.4	B.			
032335 R PERSEI—						
	3487.6	10.6	Pt.	3496.5	9.6	Ya.
035124 T ERIDANI—						
	3448.9	9.1	Kd.			
042209 R TAURI—						
	3495.6	[13.0	B.			
042215 W TAURI—						
	3462.5	11.4	Cu.	3484.7	10.6	Sg.
	3469.6	10.9	Cu.	3487.6	10.0	Pt.
	3477.7	10.8	Sg.	3495.6	10.6	B.
	3479.7	10.6	Sg.			
042309 S TAURI—						
	3495.6	[13.0	B.			
043065 T CAMELOPARDALIS—						
	3473.3	11.0	L.	3487.6	9.8	Pt.
043208 RX TAURI—						
	3481.7	12.2	Br.	3487.6	12.8	Pt.
	3486.6	12.1	B.			
043263 R RETICULI—						
	3429.0	12.4	Bl.			
043274 X CAMELOPARDALIS—						
	3471.6	12.0	B.	3488.6	9.2	B.
	3477.7	11.0	Br.	3488.6	9.8	Y.
	3487.6	9.7	Pt.			
043738 R CAELI—						
	3429.0	10.3	Bl.	3449.0	8.8	Bl.
	3440.0	9.8	Bl,			
045307 R ORIONIS—						
	3488.6	13.2	Y.			
045514 R LEPORIS—						
	3438.0	9.7	Ch.	3474.6	9.6	B.
	3461.2	9.9	Ch.	3487.6	9.3	B.
	3471.6	9.5	Ct.	3487.6	10.0	Pt.
	3472.3	10.2	L.	3497.5	9.8	Ya.
050003 V ORIONIS—						
	3474.6	[12.6	B.	3488.6	[13.	Y.
	3487.6	13.3	Pt.			
050022 T LEPORIS—						
	3429.0	8.5	Bl.	3456.8	8.8	Ml.
	3440.0	8.1	Bl.	3487.6	9.5	B.
	3451.0	8.5	Bl.	3487.6	9.8	Pt.
050848 S PICTORIS—						
	3429.0	10.0	Bl.	3449.0	10.3	Bl.
	3440.0	10.2	Bl.			
050953 R AURIGAE—						
	3481.6	9.2	Lv.	3487.6	9.4	Pt.
	3481.7	9.6	Br.	3494.6	9.7	Lv.
	3487.6	9.4	B.			
051247 T PICTORIS—						
	3429.0	8.0	Bl.	3449.0	8.5	Bl.
	3440.0	8.2	Bl.			
051533 T COLUMBAE—						
	3429.0	7.9	Bl.	3449.0	7.5	Kd.
	3442.0	7.3	Bl.	3454.0	7.8	Kd.
	3449.0	7.2	Bl.			
052034 S AURIGAE—						
	3473.3	9.6	L.	3494.6	8.8	B.
	3486.7	8.0	Pt.			
052036 W AURIGAE—						
	3472.3	11.1	L.	3486.7	11.6	Pt.
	3485.7	11.1	B,			
052404 S ORIONIS—						
	3486.7	13.0	Pt.			
053005a T ORIONIS—						
	3457.3	10.7	An.	3485.6	11.0	B.
	3465.3	10.0	An.	3486.6	10.6	Pt.
	3471.6	10.3	Pt.	3487.6	10.8	Pt.
	3472.4	11.6	L.	3489.6	10.6	Pt.
	3473.3	11.9	L.	3496.6	10.8	Pt.
	3473.3	11.7	An.	3497.6	11.0	Ya.
	3474.5	10.5	Pt.	3497.6	10.6	Pt.
	3479.3	12.3	L.	3498.6	11.0	Pt.
	3481.5	11.0	Pt.			
053068 S CAMELOPARDALIS—						
	3464.7	9.0	Jb.	3486.7	8.7	Pt.
	3467.7	9.0	Jb,	3497.6	9.0	Ya.
	3470.7	9.1	Jb,			
053326 RR TAURI—						
	3495.6	12.6	B.			
053531 U AURIGAE—						
	3486.7	12.9	Pt.	3495.6	[13.0	B.
	3488.6	11.6	Y.			
054319 SU TAURI—						
	3425.1	9.6	Ch.	3486.6	9.8	Pt.
	3458.2	9.7	Ch.	3487.6	9.8	Pt.
	3468.5	9.8	Cd.	3488.6	9.5	B.
	3471.6	9.6	Pt.	3489.6	9.6	Pt.
	3474.5	9.5	Pt.	3493.5	9.7	Y.
	3476.6	9.7	Br.	3494.6	9.5	B.
	3477.6	9.6	Br.	3496.6	9.8	Pt.
	3479.3	9.5	L.	3497.5	9.8	Cd.
	3481.5	9.5	Pt.	3497.6	9.6	Pt.
	3481.7	9.4	Br.	3498.6	9.7	Pt.
	3482.6	9.8	Br.			
054331 S COLUMBAE—						
	3429.0	13.3	Bl.			
054615a Z TAURI—						
	3493.6	[12.7	Y.			
054615b RS TAURI—						
	3493.6	9.2	Y.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star J.D. Est.Obs. J.D. Est.Obs.

054615c RU TAURI—
3493.6 [12.7 Y.

054629 R COLUMBAE—
3429.0 [13.0 Bl.

054907 α ORIONIS—
3457.3 0.7 An, 3472.3 0.8 An,
3464.3 0.9 An, 3473.3 0.8 An,
3465.3 0.7 An, 3479.3 1.0 L.
3466.3 0.8 An.

054920a U ORIONIS—
3454.0 11.0 Kd. 3486.7 11.2 B.
3481.6 11.6 Lv. 3486.7 12.0 Pt.

054920b UW ORIONIS—
3481.6 10.5 Lv.

054945 TW AURIGAE—
3449.0 8.6 Kd.

054974 V CAMELOPARDALIS—
3476.7 11.0 Br, 3488.6 11.1 B,
3484.6 10.9 Y, 3494.6 11.0 B.
3486.7 10.8 Pt,

055353 Z AURIGAE—
3494.6 9.8 Pt, 3497.6 10.3 M,
3494.6 9.8 B, 3498.6 10.5 Pt.

055686 R OCTANTIS—
3429.0 11.1 Bl. 3449.0 11.2 Bl.
3440.0 11.1 Bl.

060450 X AURIGAE—
3481.7 10.0 Br, 3486.7 9.7 Pt,
3485.7 10.3 B, 3497.6 11.5 M.

060547 SS AURIGAE—
3425.1 [11.6 Ch, 3479.3 [12.4 L,
3448.0 [11.0 Ch, 3481.5 [11.0 Pt,
3454.0 [11.0 Ch, 3481.6 [12.4 Br,
3458.2 11.4 Ch, 3482.6 [12.4 Br,
3459.3 11.2 Ch, 3486.6 [12.6 Pt,
3460.0 11.4 Ch, 3487.6 [12.6 Pt,
3461.0 11.8 Ch, 3487.6 [13.3 Y,
3462.1 [11.8 Ch, 3488.6 [13.7 B,
3470.6 [13.0 Br, 3489.6 [12.6 Pt,
3471.6 [12.6 Pt, 3489.6 [13.0 E,
3471.6 [13.5 B, 3492.6 [12.4 Br,
3472.3 [13.3 L, 3494.6 [13.9 Lv,
3472.7 [13.7 Lv. 3494.6 [13.7 B,
3473.3 [13.3 L. 3496.6 [12.6 Pt,
3474.5 [11.5 Pt, 3497.6 [12.4 M,
3476.6 [12.4 Br. 3497.6 [12.6 Pt,
3477.6 [12.6 Br, 3498.6 [12.6 Pt.

061647 V AURIGAE—
3489.6 12.2 E.

061702 V MONOCEROTIS—
3486.7 9.8 Pt.

063159 U LYNCIS—
3487.6 12.8 Y.

063308 R MONOCEROTIS—
3486.7 11.6 Pt. 3489.7 11.8 E.

063558 S LYNCIS—
3486.7 13.1 Pt.

064707 W MONOCEROTIS—
3482.6 10.8 Br. 3495.6 10.4 B.
3486.7 10.9 Pt.

065111 Y MONOCEROTIS—
3484.6 [13.3 Y, 3494.7 12.5 Lv.
3486.7 13.0 Pt. 3496.6 12.1 Ya.
3489.6 12.7 E,

065208 X MONOCEROTIS—
3472.3 7.5 L. 3496.6 8.2 Ya

065355 R LYNCIS—
3487.6 11.2 Y, 3489.6 11.3 E.

070122a R GEMINORUM—
3458.8 8.7 Wf, 3481.6 9.7 Lv,
3470.6 9.4 Lv, 3486.7 10.1 Pt,
3470.7 9.6 Lv, 3497.7 10.4 Lv.

070122b Z GEMINORUM—
3470.7 12.4 Lv, 3486.7 12.5 Pt.
3481.6 12.4 Lv,

070122c TW GEMINORUM—
3470.7 8.3 Lv, 3497.7 8.4 Lv.
3481.6 8.3 Lv,

070310 R CANIS MINORIS—
3473.3 8.4 L. 3475.6 8.3 B.

071201 RR MONOCEROTIS—
3473.7 [13.2 Lv.

071713 V GEMINORUM—
3486.7 8.9 Pt, 3497.6 9.8 M.

072708 S CANIS MINORIS—
3471.6 10.1 Ct. 3488.5 9.8 Cd,
3474.6 10.2 Cd, 3492.7 10.2 Ct.
3479.3 10.3 Ct. 3495.7 9.8 Ct.
3484.7 10.2 Sg, 3496.6 9.8 Cd.
3486.7 9.8 Pt.

072811 T CANIS MINORIS—
3486.7 12.1 Pt, 3489.6 12.0 E.

073173 S VOLANTIS—
3429.0 10.3 Bl. 3449.0 10.7 Bl.
3440.0 10.5 Bl.

073508 U CANIS MINORIS—
3479.3 9.6 L. 3493.5 10.0 Y.
3486.7 10.1 Pt.

073723 S GEMINORUM—
3489.6 13.2 E.

074241 W PUPPIS—
3429.0 9.8 Bl. 3449.0 11.5 Bl.
3440.0 10.3 Bl.

074922 U GEMINORUM—
3429.1 [11.4 Ch, 3473.2 12.8 L,
3448.0 [10.9 Ch, 3473.7 13.2 Lv,
3454.0 [12.4 Ch, 3474.5 [13.4 B,
3458.1 [12.4 Ch, 3474.5 [11.3 Pt,
3464.0 [12.4 Ch, 3481.5 [11.3 Pt,
3465.0 9.4 Ch. 3481.7 [13.0 Br,
3466.0 9.2 Ch. 3482.6 [13.0 Br,
3467.0 9.2 Ch, 3486.6 [12.4 Pt,
3468.0 9.3 Ch, 3487.6 [13.3 Pt,
3469.1 9.7 Ch, 3489.6 [13.3 Pt,
3470.1 9.8 Ch, 3492.7 [13.0 Br,
3470.7 10.5 Lv, 3494.6 [13.9 B,
3471.5 11.2 B. 3494.6 [13.7 Lv,
3471.6 11.1 Pt, 3496.6 [12.4 Pt,
3472.3 12.2 Ch, 3497.6 [11.7 M,
3472.3 11.6 L. 3497.6 [12.4 Pt,

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
074922 U GEMINORUM—Continued.						
	3472.6	12.6	B.	3498.6	[13.7	Pt.
	3472.7	12.3	Lv.			
075612 U PUPPIS—						
	3484.6	[12.9	Y.			
081112 R CANCRI—						
	3429.2	9.1	Ch.	3474.5	8.0	B.
	3441.1	8.8	Ch.	3479.3	7.2	L.
	3458.1	8.6	Ch.	3486.6	7.2	Mh.
	3461.5	8.7	Cu.	3486.7	7.0	Pt.
	3465.1	8.5	Ch.	3495.7	7.1	Mh.
	3469.6	8.4	Cu.			
081617 V CANCRI—						
	3429.2	10.1	Ch.	3486.7	12.9	Pt.
	3458.1	12.0	Ch.	3488.6	13.0	B.
082405 RT HYDRAE—						
	3449.0	8.2	Kd.	3486.7	7.8	Pt.
082476 R CHAMELEONTIS—						
	3440.0	13.0	Bl.			
083019 U CANCRI—						
	3473.7	[13.3	Lv.			
083350 X URSAE MAJORIS—						
	3486.6	12.1	B.	3486.7	12.0	Pt.
084803 S HYDRAE—						
	3424.8	8.4	Ml.	3459.6	8.3	Pw.
	3429.2	7.6	Ch.	3465.1	8.2	Ch.
	3439.6	7.7	Pw.	3471.6	9.0	B.
	3441.1	7.7	Ch.	3486.7	10.2	Pt.
	3454.1	8.0	Ch.	3492.7	10.6	Br.
084917 X CANCRI—						
	3458.4	7.3	Au.	3461.3	7.1	Au.
085008 T HYDRAE—						
	3429.2	9.0	Ch.	3463.1	7.1	Ch.
	3441.2	8.5	Ch.	3479.3	7.4	L.
	3455.1	7.8	Ch.	3486.7	7.6	Pt.
085120 T CANCRI—						
	3361.3	9.9	Au.	3486.7	8.2	Pt.
	3462.1	9.4	Ch.			
090151 V URSAE MAJORIS—						
	3486.6	9.9	B.			
090425 W CANCRI—						
	3472.6	9.6	B.	3489.7	10.3	E.
	3479.3	9.7	L.	3492.7	10.3	Br.
	3488.6	10.3	B.			
091868 RW CARINAE—						
	3440.0	13.5	Bl.			
092551 Y VELAE—						
	3429.1	11.8	Bl.	3449.0	10.4	Bl.
	3442.0	11.0	Bl.			
093962 R CARINAE—						
	3429.1	6.5	Bl.	3449.0	5.3	Bl.
	3442.1	6.1	Bl.			
093014 X HYDRAE—						
	3436.2	11.7	Ch.	3486.7	12.0	Pt.
	3462.2	11.9	Ch.			
093178 Y DRACONIS—						
	3487.6	13.4	Y.			
093934 R LEONIS MINORIS—						
	3427.2	10.2	Ch.	3487.7	6.7	Pt.
	3434.1	9.5	Ch.	3492.6	7.3	Ct.
	3455.1	8.0	Ch.	3492.7	7.0	Br.
	3463.1	7.5	Ch.	3495.7	7.3	Ct.
	3470.6	7.4	Ct.	3495.8	7.2	M.
	3472.6	7.0	B.	3494.6	6.8	B.
	3475.8	7.2	Ct.			
094211 R LEONIS—						
	3361.3	9.9	Au.	3473.8	10.0	Ct.
	3427.2	8.1	Ch.	3475.8	9.5	Ct.
	3439.6	8.6	Pw.	3485.3	8.6	Pe.
	3442.9	8.6	Pw.	3485.7	9.9	Sg.
	3455.1	9.5	Ch.	3486.6	10.2	Mh.
	3457.3	9.1	An.	3487.7	10.0	E.
	3458.3	8.8	Pe.	3487.8	10.4	Ct.
	3459.6	8.7	Pw.	3492.6	10.2	Ct.
	3465.3	9.5	An.	3495.6	10.3	Ct.
	3470.8	9.8	Ct.	3495.8	9.4	M.
	3473.3	9.7	An.			
094512 X LEONIS—						
	3473.3	[12.5	L.			
094622 Y HYDRAE—						
	3424.8	7.2	Ml.			
094953 Z VELAE—						
	3442.1	13.5	Bl.			
095421 V LEONIS—						
	3487.7	12.6	Pt.			
100661 S CARINAE—						
	3429.1	5.5	Bl.	3449.0	6.0	Bl.
	3442.1	5.7	Bl.			
101153 W VELAE—						
	3442.1	13.5	Bl.			
103212 U HYDRAE—						
	3448.3	5.3	Kd.	3461.1	5.9	Kd.
	3454.1	5.7	Kd.			
103769 R URSAE MINORIS—						
	3487.7	12.8	Pt.			
104620 V HYDRAE—						
	3429.1	8.2	Bl.	3461.2	8.8	Ch.
	3434.2	8.8	Ch.	3470.1	9.0	Ch.
	3442.1	7.9	Bl.	3487.7	7.6	Pt.
	3449.0	7.5	Bl.			
104628 RS HYDRAE—						
	3442.1	13.6	Bl.			
104814 W LEONIS—						
	3462.2	9.3	Ch.	3492.7	9.8	Br
	3487.7	9.5	Pt.	3493.5	9.8	Y.
110506 S LEONIS—						
	3462.2	11.9	Ch.	3487.7	10.0	E.
	3486.6	9.9	B.	3487.7	10.1	Pt.
111661 RS CENTAURI—						
	3429.1	10.5	Bl.	3449.0	11.4	Bl.
	3442.1	10.8	Bl.			
114441 X CENTAURI—						
	3429.1	8.0	Bl.	3449.0	8.6	Bl.
	3442.1	8.6	Bl.			
115058 W CENTAURI—						
	3429.1	9.5	Bl.	3449.0	8.3	Bl.
	3442.1	8.4	Bl.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
115919 R COMAE BERENICES—						
	3487.7	13.2	E.			
120012 SU VIRGINIS—						
	3487.7	10.9	Pt,	3487.8	11.0	E.
120905 T VIRGINIS—						
	3487.7	[12.8	E.			
121418 R CORVI—						
	3479.7	7.5	L,	3487.7	7.2	E.
	3487.7	7.0	Pt,			
122001 SS VIRGINIS—						
	3448.4	7.9	Kd,	3487.8	8.7	E.
	3479.7	8.0	L,			
122532 T CANUM VENATICORUM—						
	3487.7	7.6	Pt,	3487.8	10.5	E.
122803 Y VIRGINIS—						
	3487.8	11.5	E.			
122854 U CENTAURI—						
	3429.1	8.3	Bl,	3449.0	8.0	Bl.
	3442.1	7.6	Bl.			
123160 T URSAE MAJORIS—						
	3485.3	[11.7	Pe,	3494.6	12.6	B.
	3487.7	12.9	Pt,			
123307 R VIRGINIS—						
	3470.8	8.3	Ct,	3487.8	7.9	E.
	3475.8	7.9	Ct,	3489.7	7.8	Mh,
	3479.3	8.3	L,	3492.7	7.7	Ct,
	3487.7	7.6	Pt,	3495.7	7.7	Ct.
	3487.8	7.6	Ct,			
123459 RS URSAE MAJORIS—						
	3429.2	9.5	Ch,	3485.3	9.9	Pe,
	3458.3	9.2	Ch,	3486.6	10.0	Mh,
	3461.5	9.1	Cu,	3487.7	9.5	Pt,
	3467.2	9.2	Ch,	3487.7	10.5	Ct,
	3469.7	9.5	Cu,	3492.7	10.3	Ct,
	3473.8	9.5	Ct,	3494.6	10.4	B,
	3475.8	9.9	Ct,	3495.7	10.1	Mh,
	3478.2	9.6	Ch,	3495.8	10.5	Ct,
	3483.7	10.0	Sg,	3495.9	10.3	M.
123961 S URSAE MAJORIS—						
	3457.2	11.5	An,	3485.3	11.2	Pe,
	3465.2	11.4	An,	3487.7	10.8	Pt,
	3473.3	11.8	An,	3489.8	11.0	M,
	3479.3	11.7	L,	3495.7	10.1	Mh.
124204 RU VIRGINIS—						
	3487.7	12 8	Pt,	3487.8	12.8	E.
124606 U VIRGINIS—						
	3487.7	10.8	Pt,	3487.8	8.7	E.
131283 U OCTANTIS—						
	3429.1	7.8	Bl,	3449.0	8.3	Bl.
	3442.1	8.4	Bl.			
132003 W VIRGINIS—						
	3495.8	9.7	M.			
132203 V VIRGINIS—						
	3495.8	10.0	M.			
132422 R HYDRAE—						
	3425.5	5.3	Ch,	3455.5	4.5	Ch,
	3441.5	4.8	Ch,	3458.3	4.7	Kd,
	3442.1	4.5	Bl,	3465.3	4.6	Ch,
	3446.4	4.7	Kd,	3468.3	4.7	Kd,
	3447.4	4.6	Ch,	3472.3	4.8	Kd,
132422 R HYDRAE—Continued.						
	3448.4	4.7	Kd,	3476.5	4.8	Ch,
	3450.4	4.8	Kd,	3479.7	4.8	L,
	3453.4	4.9	Kd,	3487.7	4.2	Pt.
	3454.4	4.7	Kd.			
132706 S VIRGINIS—						
	3473.8	8.0	Ct,	3489.7	6.8	Mh,
	3475.8	7.8	Ct,	3492.7	7.4	Ct,
	3487.7	7.1	Pt,	3495.7	7.0	Mh,
	3487.8	7.2	Ct,	3495.8	7.3	M,
	3488.8	7.0	Sg,	3495.8	7.2	Ct.
133155 RV CENTAURI—						
	3429.1	8.6	Bl,	3449.0	7.8	Bl.
	3442.1	8.4	Bl.			
133633 T CENTAURI—						
	3442.1	6.2	Bl,	3451.0	6.9	Bl,
	3448.4	7.0	Kd,	3472.3	7.1	Kd.
	3450.4	7.1	Kd,			
134236 RT CENTAURI—						
	3442.1	9.2	Bl,	3451.0	4.2	Bl.
134440 R CANUM VENATICORUM—						
	3473.8	8.1	Ct,	3495.7	7.6	Ct,
	3475.8	8.2	Ct,	3495.7	9.0	Mh,
	3487.7	7.6	Pt,	3497.7	8.3	M.
	3493.8	7.7	Ct,			
134536 RX CENTAURI—						
	3442.1	11.2	Bl.			
134677 T APODIS—						
	3442.1	13.1	Bl.			
135908 RR VIRGINIS—						
	3487.7	14.0	Pt.			
140113 Z BOOTIS—						
	3458.8	11.7	Wf.			
140512 Z VIRGINIS—						
	3487.7	12.3	Pt.			
140528 RU HYDRAE—						
	3442.1	[13.5	Bl.			
140959 R CENTAURI—						
	3429 1	9.8	Bl,	3449.0	8.2	Bl.
	3442.1	9.5	Bl.			
141567 U URSAE MINORIS—						
	3446 5	9.8	Ch,	3487.7	8.9	Pt.
	3465.2	9.0	Ch,			
141954 S BOOTIS—						
	3485.7	9.9	Sg.			
142539 V BOOTIS—						
	3450.4	8.0	Kd,	3485.7	9.5	Sg,
	3458.3	8.2	Kd,	3487.7	9.4	Pt,
	3468.3	8.8	Kd,	3497.7	10.0	M.
142584 R CAMELOPARDALIS—						
	3456.8	8.3	Ml,	3487.7	8.2	Pt.
143227 R BOOTIS—						
	3473.8	7.2	Ct,	3488.8	7.5	Sg,
	3475.8	7.3	Ct,	3492.7	6.7	Ct,
	3487.7	7.5	Pt,	3495.7	6.6	Ct.
	3487.8	6.7	Ct,			
144918 U BOOTIS—						
	3495.8	10.8	M.			
145254 Y LUPI—						
	3442.1	9.1	Bl,	3449.0	8.6	Bl.

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
145971 S APODIS—						
	3429.1	10.0	Bl.	3449.0	10.1	Bl.
	3442.1	10.1	Bl.			
150018 RT LIBRAE—						
	3489.8	13.0	Pt.			
150519 T LIBRAE—						
	3489.8	11.4	Pt.			
151520 S LIBRAE—						
	3447.5	11.0	Ch.	3489.8	10.5	Pt.
151731 S CORONAE BOREALIS—						
	3442.9	7.5	Pw.	3487.8	9.1	Ct.
	3448.4	7.4	Kd.	3488.8	8.8	Sg.
	3458.3	8.2	Kd.	3489.8	8.5	Pt.
	3468.3	8.4	Kd.	3489.8	8.6	M.
	3473.8	8.4	Ct.	3493.8	9.2	Ct.
	3474.7	8.4	Cd.	3495.8	9.4	Ct.
	3475.8	8.6	Ct.			
151822 RS LIBRAE—						
	3442.2	9.3	Bl.			
152714 RU LIBRAE—						
	3489.8	9.4	Pt.			
152849 R NORMAE—						
	3442.1	7.5	Bl.			
153215 W LIBRAE—						
	3442.2	13.0	Bl.			
153378 S URSAE MINORIS—						
	3485.7	9.8	Sg.	3489.8	9.5	Pt.
153630 U LIBRAE—						
	3442.2	12.2	Bl.			
154428 R CORONAE BOREALIS—						
	3439.9	6.0	Wf.	3475.9	6.2	Jb.
	3442.9	6.5	Pw.	3476.9	6.0	Br.
	3446.5	6.3	Ch.	3477.0	6.4	Ct.
	3448.3	6.1	Kd.	3479.7	6.1	L.
	3450.4	6.2	Kd.	3482.9	6.2	Pt.
	3453.4	6.2	Kd.	3486.7	6.2	Pt.
	3458.3	6.3	Kd.	3487.7	6.5	Ct.
	3458.8	6.3	Wf.	3487.7	6.2	Pt.
	3465.3	6.2	Ch.	3488.8	5.8	Sg.
	3468.3	6.1	Kd.	3489.8	6.1	Pt.
	3470.8	6.6	Ct.	3489.8	6.2	M.
	3473.6	6.4	Jb.	3493.8	6.5	Ct.
	3473.8	6.4	Jb.	3495.8	6.5	Ct.
	3474.7	6.8	Cd.	3496.6	6.3	Cd.
	3474.9	6.2	Pt.	3498.9	6.1	Pt.
154536 X CORONAE BOREALIS—						
	3489.8	10.6	M.	3489.8	11.6	Pt.
154615 R SERPENTIS—						
	3447.5	7.6	Ch.	3489.8	6.4	Pt.
	3488.8	7.2	Sg.			
154639 V CORONAE BOREALIS—						
	3489.8	9.7	M.	3489.8	8.5	Pt.
154715 R LIBRAE—						
	3489.8	11.7	Pt.			
155018 RR LIBRAE—						
	3447.5	[11.9	Ch.	3489.8	12.5	Pt.
155823 RZ SCORPII—						
	3489.8	9.5	Pt.			

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
160021 Z SCORPII—						
	3442.2	9.4	Bl.			
160118 R HERCULIS—						
	3447.5	11.0	Ch.	3488.8	8.5	Sg.
	3473.8	8.8	Ct.	3489.8	8.9	Pt.
	3475.8	8.4	Ct.	3495.8	8.9	M.
	3487.8	8.3	Ct.			
160210 U SERPENTIS—						
	3488.8	11.0	Sg.	3495.9	10.4	M.
	3489.8	10.8	Pt.			
160221a X SCORPII—						
	3442.2	[12.8	Bl.			
160625a RU HERCULIS—						
	3479.7	6.9	L.	3493.8	7.0	Ct.
	3489.8	6.8	Pt.	3495.8	7.0	Ct.
160625b SX HERCULIS—						
	3479.7	8.9	L.	3489.8	8.3	Pt.
	3482.9	8.6	Pt.	3498.9	7.6	Pt.
161122a R SCORPII—						
	3442.2	9.8	Bl.	3489.8	12.2	Pt.
161122b S SCORPII—						
	3442.2	[12.6	Bl.	3489.8	11.6	Pt.
161122c T SCORPII—						
	3489.8	10.9	Pt.			
161138 W CORONAE BOREALIS—						
	3474.7	10.2	Cd.	3489.8	10.9	Pt.
161607 W OPHIUCHI—						
	3489.8	10.9	Pt.			
162112 V OPHIUCHI—						
	3489.8	10.0	Pt.			
162119 U HERCULIS—						
	3470.8	9.0	Ct.	3488.8	8.4	Sg.
	3473.8	8.4	Ct.	3489.8	8.0	Pt.
	3475.8	8.6	Ct.	3489.8	8.0	M.
	3487.8	8.0	Ct.	3495.8	8.2	Ct.
162807 SS HERCULIS—						
	3479.7	12.4	L.	3489.8	13.2	Pt.
162815 T OPHIUCHI—						
	3442.2	[12.8	Bl.	3489.8	11.2	Pt.
162816 S OPHIUCHI—						
	3442.2	[13.2	Bl.			
163137 W HERCULIS—						
	3446.5	8.5	Ch.	3489.8	8.8	Pt.
	3477.0	8.5	Ct.	3495.8	9.2	Ct.
	3489.8	8.7	M.			
163172 R URSAE MINORIS—						
	3489.8	10.5	M.			
163266 R DRACONIS—						
	3446.5	8.5	Ch.	3489.8	12.0	M.
	3465.3	9.6	Ch.	3489.8	10.8	Pt.
164055 S DRACONIS—						
	3495.8	9.0	M.			
164715 S HERCULIS—						
	3489.8	10.6	Pt.			
164844 RS SCORPII—						
	3442.2	11.7	Bl.			
165030 RR SCORPII—						
	3442.2	8.9	Bl.			
165202 SS OPHIUCHI—						
	3489.8	11.5	Pt.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
165631 RV HERCULIS—						
	3489.8	14.8	Pt.			
165636 RT SCORPII—						
	3442.2	[13.2	Bl.			
170215 R OPHIUCHI—						
	3489.8	11.3	Pt.			
170833 RW SCORPII—						
	3442.2	[12.5	Bl.			
171401 Z OPHIUCHI—						
	3489.8	8.4	Pt.			
171723 RS HERCULIS—						
	3489.8	12.3	Pt.			
172486 S OCTANTIS—						
	3429.0	9.7	Bl.	3449.0	11.3	Bl.
	3442.1	10.6	Bl.			
172809 RU OPHIUCHI—						
	3489.8	11.3	Pt.			
173543 RU SCORPII—						
	3442.2	10.9	Bl.			
174135 SV SCORPII—						
	3442.2	11.1	Bl.			
174162 W PAVONIS—						
	3429.0	9.2	Bl.	3449.0	10.0	Bl.
	3442.1	9.8	Bl.			
174406 RS OPHIUCHI—						
	3489.8	11.8	Pt.			
175111 RT OPHIUCHI—						
	3489.8	10.0	Pt.			
175519 RY HERCULIS—						
	3489.8	10.2	Pt.			
180531 T HERCULIS—						
	3479.7	10.4	L.	3489.8	9.2	Pt.
180565 W DRACONIS—						
	3489.8	9.5	Pt.	3496.5	9.6	Cd.
181103 RY OPHIUCHI—						
	3454.0	10.7	Jk.			
181136 W LYRAE—						
	3384.9	10.1	Jk.	3479.7	8.3	L.
	3477.0	8.5	Ct.	3498.9	9.1	Pt.
182133 RV SAGITTARII—						
	3442.2	[12.4	Bl.			
182224 SV HERCULIS—						
	3479.7	10.9	L.			
182306 T SERPENTIS—						
	3498.9	10.8	Pt.			
183308 X OPHIUCHI—						
	3479.7	6.7	L.	3498.9	6.7	Pt.
184205 R SCUTI—						
	3458.4	6.8	Kd.	3480.9	5.9	Cd.
	3468.3	5.9	Kd.	3482.9	5.5	Pt.
	3472.3	5.8	Kd.	3484.9	5.6	Cd.
	3474.9	5.8	Pt.	3489.9	5.5	Pt.
	3477.0	5.6	Ct.	3498.9	5.5	Pt.
	3479.7	5.9	L.			
184300 NOVA AQUILAE #3—						
	3474.9	10.4	Pt.	3498.9	10.1	Pt.
	3482.9	10.1	Pt,			
185512 RT SAGITTARII—						
	3479.7	8.9	L.			
190926 X LYRAE—						
	3498.9	9.0	Pt.			
191033 RY SAGITTARII—						
	3442.3	[9.2	Bl.			
191637 U LYRAE—						
	3498.9	10.0	Pt.			
193449 R CYGNI—						
	3337.8	10.3	Ml.	3498.9	10.8	Pt.
193972 T PAVONIS—						
	3442.1	[13.2	Bl.			
94048 RT CYGNI—						
	3468.5	8.0	Ch.	3489.9	8.3	M.
	3469.5	8.2	Cd.	3498.9	8.2	Pt.
194348 TU CYGNI—						
	3468.5	9.8	Ch.	3489.9	9.7	M.
194604 X AQUILAE—						
	3498.9	10.1	Pt.			
194632 χ CYGNI—						
	3351.0	5.4	Jk.	3402.0	7.3	Jk.
195142 RU SAGITTARII—						
	3428.0	6.5	Bl.			
195553 NOVA CYGNI #3—						
	3474.9	10.8	Pt.	3489.8	11.0	Pt.
	3482.9	10.6	Pt.	3498.9	11.2	Pt.
	3486.7	10.7	Pt.			
195849 Z CYGNI—						
	3489.9	9.0	M.	3498.9	8.6	Pt.
195855 S TELESCOPII—						
	3429.0	[12.6	Bl.			
200212 SY AQUILAE—						
	3479.7	9.4	L.			
200715a S AQUILAE—						
	3498.9	9.5	Pt.			
200715b RW AQUILAE—						
	3498.9	9.1	Pt.			
200747 R TELESCOPII—						
	3429.0	[12.4	Bl.			
200938 RS CYGNI—						
	3404.3	8.4	Au.	3448.9	8.2	Kd.
	3409.3	8.0	Au.	3498.9	7.3	Pt.
	3425.0	8.1	Ch.			
201139 RT SAGITTARII—						
	3428.0	7.3	Bl.			
201647 U CYGNI—						
	3407.0	11.5	Ch.	3498.9	7.5	Pt.
	3489.9	9.0	M.			
202240 U MICROSCOPII—						
	3429.0	10.8	Bl.			
202539 RW CYGNI—						
	3404.3	9.1	Au.	3489.9	9.0	M.
202946 SZ CYGNI—						
	3482.9	8.8	Pt.	3498.9	9.0	Pt.
	3489.8	9.7	Pt.			
202954 ST CYGNI—						
	3489.9	10.7	M.			
203226 V VULPECULAE—						
	3498.9	8.7	Pt.			
203847 V CYGNI—						
	3429.0	9.6	Ch.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1923—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
204954 S INDI—						
	3429.0	8.4	Bl.	3449.0	8.8	Bl.
	3440.0	8.6	Bl.			
210382 X CEPHEI—						
	3487.6	8.9	Y.			
210868 T CEPHEI—						
	3385.9	10.4	Jk.	3455.0	7.9	Ch.
	3429.1	8.8	Ch.	3473.3	7.2	L.
	3441.0	8.2	Ch.	3497.6	7.7	Ya.
213244 W CYGNI—						
	3447.9	6.5	Kd.	3472.3	6.4	Kd.
	3454.9	6.4	Kd.	3472.3	5.7	L.
	3459.9	6.4	Kd.			
213678 S CEPHEI—						
	3497.6	10.0	Ya.			
213753 RU CYGNI—						
	3436.1	8.5	Ch.			
213843 SS CYGNI—						
	3351.0	8.1	Jk.	3448.0	8.5	Ch.
	3354.0	8.5	Jk.	3448.9	9.1	Kd.
	3355.0	8.9	Jk.	3451.0	8.9	Ch.
	3356.1	9.2	Jk.	3452.9	9.6	Kd.
	3385.9	10.4	Jk.	3453.9	10.1	Kd.
	3386.9	9.7	Jk.	3454.0	10.0	Ch.
	3401.9	[10.9	Jk.	3455.0	10.5	Ch.
	3425.1	12.0	Ch.	3470.6	11.9	Br.
	3429.1	11.9	Ch.	3472.3	11.8	L.
	3436.0	11.8	Ch.	3473.3	11.9	L.
	3437.1	11.7	Ch.	3473.3	11.8	An.
	3438.1	11.1	Ch.	3474.5	11.7	Pt.
	3439.0	9.4	Ch.	3479.3	11.8	L.
	3441.0	8.3	Ch.	3482.9	11.8	Pt.
	3443.0	8.4	Ch.	3489.8	11.9	Pt.
	3444.0	8.3	Ch.	3489.9	[10.4	M.
	3446.0	8.3	Ch.	3495.9	8.3	M.
	3447.0	8.5	Ch.	3498.9	9.8	Pt.
213937 RV CYGNI—						
	3404.2	8.5	Au.	3498.9	6.8	Pt.
222439 S LACERTAE—						
	3479.3	10.5	L.			
222867 R INDI—						
	3429.0	9.0	Bl.	3449.0	9.2	Bl.
	3440.0	9.0	Bl.			
223841 R LACERTAE—						
	3473.3	13.2	L.			
224354 U LACERTAE—						
	3444.3	8.8	Au.	3449.3	9.2	Au.
230759 V CASSIOPEIAE—						
	3430.3	11.8	Au.	3444.3	12.3	Au.
	3437.3	12.4	Au.	3458.3	11.7	Au.
231425 W PEGASI—						
	3472.3	9.0	L.			
233335 ST ANDROMEDAE—						
	3429.1	9.0	Ch.	3467.1	9.4	Ch.
	3455.1	9.5	Ch.			
233815 R AQUARII—						
	3425.1	7.9	Ch.	3453.9	6.3	Kd.
	3435.1	6.5	Ch.	3455.0	6.0	Ch.
	3447.0	6.2	Ch.	3459.9	6.2	Kd.
	3447.9	6.4	Kd.			
235209 V CETI—						
	3429.0	9.3	Bl.	3448.9	10.1	Kd.
	3440.0	9.6	Bl.	3449.0	9.5	Bl.
235350 R CASSIOPEIAE—						
	3444.3	8.0	Au.	3458.3	8.6	Au.
	3449.3	8.3	Au.			
235525 Z PEGASI—						
	3448.9	9.5	Kd.			
235715 W CETI—						
	3448.9	8.9	Kd.			

Total Observations: 1.091. Stars Observed: 287. Observers: 24.

COMMUNICATIONS.

The Spot Light as a Pointer.— A convenient and surprisingly efficient pointer for indicating positions on the celestial sphere is afforded by the accessory "spot light" carried on many motor cars.

This sharp beam of light has the appearance of almost touching the celestial sphere and with a well focused reflector positions down to a degree of arc are indicated. The lamp is of light weight, has an extension cord, and is easily held in the hand and manipulated. Stars and planets can be pointed out without confusion to persons within a radius of ten feet of the teacher, the beam of light being about 150 feet long and presenting the most surprising illusion of almost touching the star sphere. To the teacher and to the learner of uranography alike it is of great assistance. Its use serves to abolish a world of confusion, both in teaching and acquiring this branch of knowledge.

Red Oak, Iowa. B. F. GILLMOR.

The Occultation of Venus, at Jacksonville, Fla.— I have read many reports of the occultation of the planet Venus by the moon on January 13, 1923, from observers in the northern and eastern states, but none from Florida.

For several reasons this occultation must have reached its greatest perfection as a phenomenon of intellectual beauty here in Florida.

We have no observatories in Florida—few telescopes and fewer persons interested in astronomy—a deplorable affair with such splendid climatic conditions, and so many of the Southern Constellations full of glorious objects not visible to observers at the northern observatories. Owing to numerous, short, heavy rains in all months of the year and part of the year every day, the atmosphere of Florida, Cuba, and surrounding islands is kept clean and clear, which—even with no altitude, makes astronomical vision especially good. The moon, the planets, stars, nebulae and clusters stand out vividly on this background of clean, clear blue sky.

The morning of January 13 was ideal for "good seeing." The air was cool and crisp and very still. The whole of the sky was absolutely free from clouds during the whole of the day and night of that date. As the moon and Venus arose from the horizon in the deep dark of the early morning, it seemed that I might walk over a few miles and lay my hands on both of them. At 5:10, only a few degrees above the horizon and about three degrees apart, these two brilliant crescents, shining in a mixture of silver and gold, stood as the richest and most beautiful celestial scene that I have ever perceived. As the two bodies approached each other, each seemed to become fuller and brighter. At 6:08 a swelling appearance of the moon's limb seemed to grasp the rays of Venus and at 6:09 a great sparkling drop hung on the very edge of the Moon's crescent, and exactly at its centre. The fascination of this apparent distortion of the moon at this moment caused one to almost forget the scientific importance of correct observation. The drop became smaller and smaller until final disappearance at 6:10. After a lapse of one hour and forty minutes the emersion of Venus came suddenly on the opposite side at 7:30. The immersion occurred at the center of the edge of the moon's crescent. I observed with a Carl Zeiss glass and noted all contacts, though they are probably not accurate enough for print. As the sun rose higher both Venus and the moon lost their great brilliancy, but at noon each could be distinctly seen with the naked eye.

Among the many remarkable occurrences of nature that I have observed, this occultation ranks as a pure, fine and rare phenomenon.

Jacksonville, Florida. JENNIE LYNNE KYLE.

The Aurora of March 24, 1923. —Auroral displays constitute one of the most beautiful and awe-inspiring of natural phenomena. Though representing a form of electric discharge, they lack the terrific destructive force of the thunder bolt, and may be observed without fear of bodily harm. Early in the evening of March 24 a small patch of hazy light near the northern horizon indicated that an aurora might be seen later, although it was not until nearly 9:30 P. M. that any pronounced activity began to manifest itself. At this time the auroral arch was very pronounced and extended with unbroken intensity throughout its length. In color it was of a pale yellowish green. The space immediately below the band of light forming the arch, and extending from it to the horizon, was a dense black and apparently opaque, for no stars could be seen through this opening.

At 9:50 P. M. the arch began to show signs of agitation, which at first consisted of a sort of slow "boiling" action. This process served to break up the band of light into a broad streak of nebulous light, interspersed here and there with dark opaque clouds. By 10:00 P. M. streamers commenced to shoot up from the turbulent mass below, some being very broad and of a pale green or white, while others were extremely narrow and very brilliant green in color. Only the brighter stars were now visible and the streamers were constantly wavering to and fro over the sky. Spraying out at times like a fountain, dying away again, only to spring up into renewed splendor at another point, these shafts of light seemed almost alive. At 10:17 P. M. a most intensely bright beam of green light shot forth from the hazy glow near the horizon, traveled with great speed, in an undulating wave-like motion, nearly to the zenith, hung stationary for about two minutes, faded, split into four narrow streamers, glowed with greater intensity for an instant and died away.

The display now rapidly diminished in brilliancy and at 11:00 P. M. only a few pale narrow bands of white light remained to mark the position of the aurora.

An interesting phenomenon noted in connection with this event was the marked decrease in audibility of radio telephone signals. Each fluctuation of the auroral light caused a hissing sound to manifest itself in the radio receivers. Also at times a crackling noise, entirely different from the regular "static," could be heard. Once, when the activity was at its greatest, all three tubes of the receiving set exhibited a blue glow in their interior. This effect could only have been due to a very high voltage, acting on the grid and plate elements of the audion tubes, and must have been induced by the aurora. No signals could be received at this time, the instrument apparently being paralyzed.

The magnetic needle showed great perturbations throughout the display, several of the deflections being more than twenty degrees. This was the first aurora seen here since October 31, 1922, and was a much finer example than that one.

LEWIS J. BOSS.

North Scituate, R. I., March 26, 1923.

The First Day of Spring?—Following is a copy of an article from a recent issue of a Dubuque, Iowa, newspaper:

WEATHER MAN TELLS WHY MAR. 21 IS THE FIRST DAY OF SPRING.

According to ————, local weather forecaster, tomorrow, Mar. 21, is the first day of spring.

At 9:28 A. M. Wednesday morning the sun will cross the equator on its annual march northward.

Just how the weather man arrives at the conclusion that Mar. 21 is always the first day of spring was explained by Mr. ————. Here's the dope:

"The equator itself," he states, "is now in the ecliptic.

"What were vertical circles in the horizon system, and hour circles in the equator system, are now ecliptic meridians.

"As almucantars became parallels of declination, so now the parallels of declination became parallels of celestial latitude.

"The word Equinox signifies equality of day and night; and tomorrow the first day of spring—the day and night will be exactly of the same length."

And that's that.

Just how the sun crossing the equator could cause the "equator itself" to get into the ecliptic; and how the sun being on the vernal equinox could cause vertical circles in the horizon system, and hour circles in the equator system to

become ecliptic meridians is somewhat of a mystery; as well as to cause almucantars to become parallels of declination, and parallels of declination, in turn, to become parallels of celestial latitude. Verily this is some magic.

With reference to the causes of spring, this sounds about as intelligent as the groundhog theory of the weather. Possibly it is groundhog astronomy. May we not next expect to hear of the sun getting into the moon, the earth turning itself into a peanut roaster, all of the atmosphere getting into the politicians, and the weather bureau finding itself out of a job?

Of course, it seems that the statements were copied from Todd's Astronomy, at the bottom of page 37, where the author was explaining the ecliptic system of reference after having just finished the horizon and equator systems, but the writer was making no reference to the causes of spring or the explanation of the equinoxes, which came later in the article. Hence the explainer of spring appears to have foundered in deep water. The mysterious array of big words, swaggering in their seven-leagued boots, seem to have got tangled up in a case of the spring fever.

KENNEN D. HERMAN,
Former Government Observer, and Meteorologist in the
Science and Research Division, U. S. Army.

320½ So., 5th St., Springfield, Ill., April 2, 1923.

A Meteoric Satellite?— The article by Professor Pickering in the February number of POPULAR ASTRONOMY, "A Meteoric Satellite," reminds me of a strange object that I saw nearly two years ago, while viewing the moon through my 6-inch refractor, using a power of 40 (my mounting is equatorial, clock driven).

While viewing the moon on this occasion a small black dot appeared on the disc of the moon and traveled across the moon's disc in about 6 or 8 seconds. The diameter of the black object was probably about 3 or 4 seconds of arc,—so small that I could not detect any shape other than round. It's path was near the center of the moon, passing just a little south of Kepler, then near the Apennines and passed off near the Sea of Conflicts.

My first thought was to change to a high power eye-piece, but I realized that it was moving too fast to allow the change, so I watched it through the low power.

I do not remember the date nor the time of evening, the moon was nearly full, about 12 or 13 days old.

At the time I thought it was a common meteor so far out from the earth that its velocity would cause it to cross the apparent face or disc of the moon in 6 or 8 seconds. I have seen dozens of birds cross the field of vision, but *this* object was much farther away and consumed much more time in its transit.

R. M. MORAN.

Fairmont, W. Va., March 19, 1923.

A Bright Meteor.—Today, at 5:55 P. M., just as I had turned west from Georgia St. and on to the north sidewalk of W. 18th St. of this city, I saw an intensely brilliant shooting star 10 or 12 degrees below the star Altair. The phenomenon became visible to me about 5 degrees to the right of a vertical line dropped from the star named, and moved with great speed

well beyond the left of the vertical indicated and in a slightly downward curve.

The nucleus, or head, shone with an intensely brilliant blue-white light, something like a powerful arclight about two blocks away. In its path followed a short and apparently detached train of red glowing matter. This train of glowing matter impressed me as being composed of distinct particles. The phenomenon occurred within the interval of one second of time and disappeared noiselessly as suddenly as it had appeared.

ARTHUR JOHNSON.

Los Angeles, Calif., Dec. 22, 1922.

GENERAL NOTES.

Dr. Robert G. Aitken has been appointed Associate Director of the Lick Observatory, the appointment dating from July 1, 1923. Dr. Campbell, who was recently elected to the Presidency of the University of California, continues as Director of the Observatory, with duties confined very largely to the general policies of the institution, the Associate Director being responsible for the detailed administration.

Dr. Aitken has been a member of the Lick Observatory staff continuously from the year 1895; as Assistant Astronomer until 1907, and thereafter as Astronomer.

Beginning with July 1, 1923, correcpondence concerning the Lick Observatory should be addressed to Dr. W. W. Campbell, President's Office, University of California, Berkeley, or to Dr. R. G. Aitken, Lick Observatory, Mount Hamilton, as may best accord with the principles governing the administration of the Observatory.

Professor Barnard's Will.—It was characteristic of Professor Barnard that he should will his house, his books and his medals to the Yerkes Observatory.

Dr. John G. Hagen, S. J., Director of the Vatican Observatory, according to the *Jahresbericht* of the German Mathematical Society **31** (1922) 72, was elected a Foreign Member of the Royal Academy dei Lincei (Class of Physics and Mathematics).

The Lick Observatory Einstein Plates. — The following telegram, forwarded from Harvard College Observatory April 12, seems to indicate that the plates taken by the Crocker expedition from the Lick Observatory at Wallal, Australia, September 21, 1922, confirm the 1919 British photographs, in showing a deflection of the light of stars passing near the sun, in accord with that predicted by Einstein.

"Campbell telegraphs three pairs Australian Tahiti eclipse plates measures by Campbell, Trümpler sixty two to eighty four stars each five or six measurements completely calculated give Einstein deflection between one decimal fifty nine and one decimal eighty six seconds arc mean value one decimal seventy four."

From the April number of the *Journal of the Royal Astronomical Society of Canada* we learn that the eclipse plates taken by the Canadian Expedition and

measured by Dr. R. K. Young of Victoria, B. C., also confirm the Einstein theory. "There is undoubtedly a shift of the star images, and approximately of the amount predicted by Einstein."

Asteroid (916) America. — The naming of a little planet, one of the thousands that roam the space between Mars and Jupiter, may be a small matter, but to astronomers the little asteroid "America," in the light of the following letter, addressed to Professor Frost, will be another evidence of friendliness between American and Russian scientists.

Russian Astronomical Observatory,
Pulkowo.
23 March, 1923.

Dear Professor Frost:

The Council of Astronomers of the Pulkowo Observatory, in a meeting held on February 24, 1923, stated:

"In commemoration of the friendly relations of the astronomical observatories and astronomers, to give to the minor planet 916 Σ 1, discovered at Simeis by G. N. Neuymin, the name "America," and charged me to communicate this decision to you as Chairman of the Committee of Relieving the Russian Astronomers.

Most respectfully yours,

A. IVANOFF (Sgd.)
Director of the Pulkowo Observatory.

The Sun's Motion.—Dr. G. Strömberg has reported results of the investigation of the distribution of the velocities of 1300 stars of spectral types F to M in *Contributions from the Mt. Wilson Observatory*, No. 245. Among other interesting results he finds that the solar motion derived from these stars is dependent not only on the spectral types but also on the absolute magnitudes of the groups of stars used. Giant stars of later types give the declination of +44° for the apex of the sun's way, of earlier types +27°, while dwarf stars give +30°. The solar velocity derived from the giants is 18.8 km and from the dwarfs 31.7 km/per sec.

A "Watchman of the Stars" Passes On. — The following copy of an editorial in the Kansas City Star, Feb. 8, 1923, is a fine tribute, not only to Professor Barnard but also to the science which Barnard loved so well and served so well.

The world of science honors its great men in various ways; philosophers, alchemists, astronomers go through life with strange capital letters affixed to their names to designate their rank and titles. Yet what of the world of business and commerce, what time has it to note the passing of one of these super-scientists laboring in abstract fields?

Dr. E. E. Barnard, astronomer, who spent a good share of his life behind a photographing telescope, died Tuesday at his home near the great observatory at Williams Bay, Wisconsin, on the shores of beautiful Lake Geneva. His passing is mourned by the scientific world, naturally, because that is a world that feels its loss. Time will come when the world of business will realize that it, too, is a loser in the death of an eminent scientist like Dr. Barnard.

For astronomy, although a subject usually detached from the walks of everyday life, does hitch up with the affairs of the world, as the war department

found out when it was able to increase enormously the effectiveness of its artillery practice in the last days of the war by getting a famous astronomer, Professor Moulton of the University of Chicago, to take charge of the development of range finding.

Astronomical investigators usually are content to live apart with their studies, even as Professor Barnard, working alone one night, flashed to the world that he had located the Pons-Winnecke comet. But they are accumulating information that extends the range of human intelligence and that at any time may prove of transforming value in practical life.

A Columbus or a Cabot discovers a continent. An astronomer discovers trillions of unexplored worlds. But more—astronomers discover things that may make men think. And who can estimate the value to the world of a scientist whose work can stimulate the too often waning imaginations of these poor dwellers on this infinitesimally small sphere we call "the world?"

(By E. B. Garnett, Sunday Editor.)

Occultation of Aldebaran April 19, 1923. — The occultation of Aldebaran (α Tauri) on the afternoon of April 19 was observed by Dr. C. H. Gingrich with the 5-inch guiding telescope to the photographic telescope at Goodsell Observatory. The times were taken from the Bond Chronometer 374 by students Horace Goodhue and Katharine Woods. The image of Aldebaran was clear and sharp but unsteady.

	Corrected Chronometer Time	Central Standard Time
Immersion	$5^h\ 21^m\ 21\overset{s}{.}0$	$3^h\ 46^m\ 05\overset{s}{.}6$
Emersion	6 47 35.0	5 12 05.4

Another Daylight Occultation of Aldebaran. — A second daylight occultation of Aldebaran will happen about noon on July 10. The moon's age will be 26.3 days, or 3.2 days before New, and it will be about 40° from the sun. For these reasons the occultation may not be observable except under the best conditions. The phases for Washington and Omaha are as follows, the times being Central Standard.

	Immersion	Emersion
Washington	12:36, S 89° E. T 36° L	1:44, S 83° W, B 29° R.
Omaha	12:10, N 89° E. T 45° L	1:29, S 80° W, B 30° R.

Globular Star Clusters and Spiral Nebulae. — In *Astronomische Nachrichten* No. 5215 Professor J. Hopmann of the Bonn Observatory has discussed the question of the distances and dimensions of the globular star clusters and spiral nebulae. From the material presented he comes to the conclusion that Shapley's values for the globular star clusters are confirmed and that, while the spiral nebulae are composed of many stars, they are to be compared with the clusters in dimensions and distance and are not "island universes" comparable with our stellar system.

Globular Cluster Containing Long Period Variables. — The variable stars in the bright southern cluster 47 Tucanae are of special interest. Four of them are at maximum the brightest among the twenty thousand stars shown

on the best photographs. Their chief value lies in the fact that they are not the usual Cepheid variables, common in globular clusters, but belong to the long period class of variable stars.

More than a hundred photographs, made in the interval 1893-1922, are now available at Harvard for the study of these variables. Periods have been determined for the three brightest. The elements and limiting photographic magnitudes are as follows:

Variable	Epoch of Maximum	Period	Maximum	Minimum
		d		
1	J. D. 2412717	211.3	11.0	14.4
2	2412685	203	11.0	14.2
3	2412755	192	11.0	14.3

The similarity of these three stars in period, range, and absolute magnitude, suggests an unexpected uniformity for long period variables. All three fall within the boundaries of the cluster as outlined by the fainter stars. The range of variation is typical for variables of this class for which the period is in the neighborhood of two hundred days.

The seven known variables in 47 Tucanae were found by Professor Bailey, and positions relative to the center of the cluster are given in Harvard Annals **38**. All the plates have been measured and the reductions made by Miss Woods. The data are insufficient for the determination of periods for the other four variables, which are from one to two magnitudes fainter at maximum than the three discussed in this note.

An unpublished discussion of the brighter stars in 47 Tucanae by the writer gives a value of the parallax that indicates a high absolute magnitude for these long period variables, in fair agreement with values of the mean absolute magnitude derived for the galactic long period variables of known proper motion and radial velocity.

Harvard College Observatory Bulletin 783.
Cambridge, Massachusetts, March 19, 1923.

Meteor Radiant. — Further study of the meteor radiant reported in Harvard Bulletin 778 has been made by Professor King. Measures of points located on the paths of the several trails give by computation a more accurate position of the radiant. The 1900 position, thus determined, is $6^h\ 16^m.4$, $+15°\ 45'$, with an error not exceeding 10′. The position angles of the trails of the three meteors are 88°, 122°, and 314°. The trails, taken in the same order, begin at 5°, 4°, and 32° from the radiant, and are 2°, 1°, and 7° in length. All the trails terminate in explosions, showing conclusively that the motion in each case was outward from the common center.

By using R. A. = 94° 26′, Dec. = + 15° 44′, as the apparent place of the radiant for 1922, a reduction by Bauschinger's method for a parabolic orbit gives the following data:

Apex	(L)	118° 5′	Long. of Perihelion	(π)	104° 44′
App. Long.	(l′)	94° 18′	Long. of Asc. Node	(Ω)	27° 10′
True Long.	(l)	77° 18′	Inclination	(i)	164° 11′
App. Lat.	(b′)	— 7° 39′	Perihelion Distance	(q)	0.605
True Lat.	(b)	—12° 16′			

No correction was made for zenith attraction or diurnal aberration.

Harvard College Observatory Bulletin 783.
Cambridge, Massachusetts, March 19, 1923.

RS Cygni, 200938. — For many years this very red variable (spectral class N) has been considered as irregular in period. Little attention appears to have been given in the catalogues to Bohlin's elements: Min. = J. D. 2412004 + 420^d · E, published in 1902 (A. N. 159, 275). A recent paper by Ludendorff (A. N. 217, 174) cites the formula: Min. = J. D. 2419094 + 409^d · E. Both of these authorities considered the determination of maxima as too uncertain for deriving a period.

A discussion by Mr. Campbell of 18 maxima and 18 minima, observed since 1902, gives the elements: Max. = J. D. 2412292 + 413^d · E. The average deviations for the values of the period, as derived from successive observed maxima and minima, are 11 days and 12 days, respectively. The value of M — m is 201 days, giving (M — m) / P = 0.49. The mean light curve derived from these same observations has a long flat maximum; the light gradually decreases to a narrow, better defined minimum, and then increases more rapidly to maximum. The mean range is one magnitude. The greater part of the uncertainty in observing the star and in determining the dates of maxima and minima may be accounted for by its intense redness.

The elements given by Bohlin satisfy the early published maxima and minima better than the most recent formula, indicating a possible change in the period.

Harvard College Observatory Bulletin 783.
Cambridge, Massachusetts, March 19, 1923.

Eight Hundred and Fifty New Nebulae. — It is generally believed that the northern galactic hemisphere is richer than the southern in nebulae of the spiral family. For the spirals and spindles brighter than the tenth magnitude this belief apparently is justified; but it may depend to some extent on the incompleteness of the surveys of the southern sky. We know little as yet concerning the distribution of the fainter nebulae of this class, except that they are relatively infrequent near the Galaxy and that there is a tendency to form loose clusters. Photographs made with the Bruce telescope at Arequipa considerably supplement the data for nebulae not easily reached from northern observatories. (*Cf.* H. B. 773.)

A photograph made on September 19, 1922, with an exposure of six hours, centered on 22^h 40^m, — 45°, has been examined by the writer and eight hundred and fifty new nebulae found. A second exposure of two hours, made on the following night, shows all the objects brighter than the eighteenth magnitude. These new nebulae are not of the nature of the faint irregular nebulous wisps frequently found in the vicinity of bright spirals. Rather, they are distinct nebulae, the fainter ones almost exclusively oval or circular in form, distributed over an area of about thirty square degrees.

Only three nebulae of the N. G. C. fall within this region, and three from the second Index Catalogue. The integrated photographic magnitudes of the fifty brightest range from 10.5 to 15.5, and for the remainder the photographic magnitudes extend to nineteen or fainter.

At the eighteenth magnitude, on many parts of the plate, nebulae are more numerous than the stars.

The brighter nebulae, almost without exception, are elongated, or show spiral structure, while the fainter appear to be largely globular. It may be that the preponderance of the circular form among the fainter objects is largely a

photographic phenomenon, since many of the bright nebulae, on a short exposure, lose the faint extensions that reveal their truly elongated shape.

Positions and descriptions of these nebulae will be published later in the Harvard Annals.

Harvard College Observatory Bulletin 784.
Cambridge, Massachusetts, April 2, 1923.

New Planetary Nebula. — On a spectrum photograph, taken in 1922 with the 24-inch Bruce telescope, Miss Cannon has found a new planetary nebula for which the position for 1900 is $17^h\ 47^m\ 54^s$, $-34°\ 21'.0$. The galactic coördinates are longitude 324°, latitude $-6°$. The spectrum is typical of faint objects of this class.

Harvard College Observatory Bulletin 784.
Cambridge, Massachusetts, April 2, 1923.

The Period of W Persei, 024356.—For many years the period of the variable star W Persei, spectral class Mc, has been considered irregular. Hartwig formerly derived a period of 358 days, but later abandoned this value. Bohlin derived a value of 318 days from a discussion of the few maxima then at hand (A. N. **159**, 272, 1902). A discussion by Mr. Campbell of all the available visual observations, from 1893 to the present time, indicates that the period has averaged about 496 days, with extremes lying between 400 and 600 days. Since 1917 the period has remained near the average value.

The observations are well represented by the formula:

$$\text{Max.} = \text{J. D. } 2412720 + 496^d \cdot E$$

The average value of $M - m$ is 2.32^m, and $M - m/P = 0.49$. The amplitude of light variation is small, the mean value being 1.3 magnitudes. The maxima are of long duration, while the minima are usually short and narrow. The increase in light is slightly more rapid than the decrease.

Harvard College Observatory Bulletin 784.
Cambridge, Massachusetts, April 2, 1923.

The Accuracy of Modern Longitude Determinations. — Special Publication No. 92 of the U. S. Coast and Geodetic Survey gives valuable information on this subject. The transit instruments used by the Survey are of about 3 inches aperture and are either of the ordinary or "broken" type and equipped with transit micrometers. The severest test of the accuracy of longitude work as well as of the clock corrections on which they depend is furnished by the closing error of loops of differences in longitude. In this Publication the results of work on 18 loops involving 98 longitude differences are tabulated. A loop is defined either as a series of differences tied into two adjusted stations of the 1897 longitude net adjustment, or of differences which close on a single station. Among the 98 longitude differences there are two in which transit micrometers were not used. The average correction of the 98 differences to close the loops is $0^s.011$. The correction per difference for 10 of the loops is less than $0^s.010$, and only four loops have corrections per difference greater than $0^s.015$. The average difference correction of $0^s.011$ amounts to about 23 feet in latitude 45° and, as some of the differences were from 200 to 300 miles in length, the high order of the accuracy of the work can be appreciated.